FANUC AC SERVO SOFTWARE

90D3 Series
90E3 Series

LEARNING FUNCTION

Operator's Manual

1. Overview
2. System Configuration
3. Application Examples
4. Explanation of Learning Control
5. Servo parameters
6. Learning Control functions
7. Functions detail
8. Tuning
9. Attentions

Appendix 1. Notes on the order
Appendix 2. Making method for cutting data
Appendix 3. Parameter table for Learning Control
Appendix 4. Functions table for Servo edition
Appendix 5. Method of changing parameter in CNC Program
Appendix 6. Parameter number difference between series 16*i* and 30*i*
Index

(CAUTION)
The contents of this manual may be changed as a result of improvements to the servo software or other improvements.

				Title	90D3 / 90E3 Learning Control Operator's Manual
				Draw No.	A - 63639E - 108
01	'05.04.20	N.Sonoda	Newly designed	FANUC LTD	Sheet 01 / 064
Edit	Date	Design	Description		

Contents

1. Overview 3
2. System Configuration 5
3. Application Examples 6
   3.1 Lead Cutting 6
   3.2 Piston Lathe 7
   3.3 Cam grinder 8
4. Explanation of Learning Control 10
   4.1 Summary of Learning Control 10
   4.2 Learning Control 11
   4.3 Preview Repetitive Control 12
5. Servo parameters 13
   5.1 Setting parameters 13
   5.2 Setting High-gain parameter 17
   5.3 Setting Learning HRV3 , HRV4 18
   5.4 Servo parameters List 20
   5.5 Servo parameters detail 24
6. Learning Control functions 27
   6.1 Learning Control parameters 27
   6.2 Adaptive Preview Control parameters 33
   6.3 Adaptive method 35
7. Functions detail 36
   7.1 Learning memory expanded function 36
   7.2 Learning data transmission function 39
   7.3 Torsion compensation during high speed cycle cutting function 44
   7.4 Tandem Learning control function 45
   7.5 Position error monitoring function 49
8. Adjustment 50
9. Attentions 51

Appendix 1. Notes on the order 54
Appendix 2. Making method for cutting data 55
Appendix 3. Parameter table for Learning Control 56
Appendix 4. Functions table for Servo edition 60
Appendix 5. Method of changing parameter in CNC Program 61
Appendix 6. Parameter number difference between series 16*i* and 30*i* 62

Index 64

1. Overview

This manual only describes the special functions and parameters in FANUC Digital AC Servo applied to **Learning control** with **High-speed Cutting** (G05).

- ***High-speed Cutting*** (G05) means "**Memory operation**" by High-speed Cycle Cutting, "**DNC operation**" by Personal Computer through HSSB, or "**Data Server operation**" by High-speed binary operation.

The merit and major specification of Learning control

The Learning control by digital servo software enables high-precision control for the command and the cutting disturbance given repeatedly at specified intervals. For example, the lead for video cam drum, the piston or the camshaft for car engine is usually produced with a conventional cam machine using mechanical way. Learning control enables the customer's program to replace a conventional cam machine with a CNC machine.

- Learning period Max. **262** sec.
- Learning memory size **524,288** words (262 sec. as Learning period)
- Pulse distribution period Min. 0.25 msec. (Depending on CNC software version)
- Frequency Band Max. **1,400** Hz (only Learning HRV4 control)
- Profile number Max. **24** profiles
- Learning step number Max. 5 steps
- Learning data transmission speed **32,000** words/sec. between CNC and Servo
  All data transmission is **18.4** sec.
  Possible to transfer 4 axes at the same time
- Learning data clear speed **128,000** words/sec. (All data clear takes **4.5** sec.)

(Note) Boldface is improved from series 16*i*

Table 1-1. Combinations of Servo Software Series and CNC type

For general cutting tools		For High-speed cutting tools		Remarks
Servo	CNC	Servo	CNC	
9080	Series 16-C, 18-C Series 15-B	9083 9087	Series 16-B, 18-B Series 16-C, 18-C	HRV ↓
9090	Series 16*i*-A, Series 18*i*-A			FSSB
90A0	Series 16*i*-A, Series 18*i*-A	90A3 90A7	Series 16*i*-A, Series 18*i*-A	HRV2 ↓
90B0	Series 16*i*-A, B Series 18*i*-A, B	90B3 90B7	Series 16*i*-A, B Series 18*i*-A, B	HRV3 ↓
90D0	Series 30*i*-A Series 31*i*-A	90D3	Series 30*i*-A Series 31*i*-A	HRV4
90E0	Series 30*i*-A Series 31*i*-A Series 32*i*-A	90E3	Series 30*i*-A Series 31*i*-A	HRV3 (4-axes /DSP)

Note

1) Learning control requires Servo software 90D3 or 90E3 called **Learning series**. This manual doesn't mention about 90E3 series because it is developing. 90E3 series corresponding to 90E0 series enables to control 4-axes per one DSP.

Learning control only works during G05 execution, which is High-speed cutting in the part program. As you can set Learning control to each axis, you can mix **Learning axes** and Normal axes.

In the servo axis allocation (No.1023), Learning axis (No.2019#6=1) must be allocated to the odd axis (L-axis). The subsequent even axis (M-axis) can be used as the normal axis.

Learning control requires specific servo axis card (A20B-3300-0450). Refer to **Appendix 1**. **Notes on the order**. Never use the servo software out of accord with the above table (Table 1-1)

90D3, 90E3 series support all function of normal servo software 90D0, 90E0 series. For that reason, the parameter number for Learning control is different between series 16*i* and series 30*i*. Refer to **Appendix 6. Parameter number difference between series 16*i* and 30*i*.**

The special parameters described in this manual are applied only to Learning axis. The servo parameters except for Learning parameters are the same as that for general cutting tools. Concerning the other servo parameters except for Learning parameters described in this manual and adjustments, refer to "FANUC AC Servo Motor α *is* /α *i* /β *is* series Parameter Manual" B-65270E.

Refer to the following CNC manual.

- " FS 30*i* /300*i* /300*i*s-A Specification Manual " : B-63942E
- " FS 30*i* /300*i* /300*i*s-A Connection Manual (function) " : B-63943E
- " FS 30*i* /300*i* /300*i*s-A User's Manual " : B-63944E
- " FS 30*i* /300*i* /300*i*s-A Maintenance Manual " : B-63945E
- " FS 30*i* /300*i* /300*i*s-A Parameter Manual " : B-63950E

2. System Configuration

There are three below cases about High-speed cutting (G05). Fig.2-1 shows a system configuration.

(1) **Memory operation** by High-speed cycle cutting

a) Produce cutting data by Open CNC or personal computer and down load to **P-code area** in CNC.

b) Produce cutting data by **Macro executor** and write to P-code area.

After cutting data was prepared by personal computer or Open CNC.

(2) **Data Server operation** by High-speed binary operation

c) Produce cutting data by Open CNC or personal computer and down load via Ethernet to **Data server** and run Data Server by High-speed binary operation.

(3) **DNC operation** that Open CNC or personal computer run directly CNC through HSSB

d) User's program including DNC operation library.

e) DNC operation management package in BOP2 (**B**asic **O**peration **P**ackage 2).

Note

- In case of (3), there is a possibility that transmission rate isn't always guaranteed due to the personal computer performance. If you need to have the transmission rate guaranteed, you should select the method of c).
- You can switch the Memory operation and either Data Server operation or DNC operation in one system. You can switch two operations by G05 code or M198 code in your cutting program.
- The call of binary program from Data server is available with M198 code, not M98 code.
- In case of Memory operation, you can use "High-speed cycle skip function" or "High-speed cycle retract function". In case of (2) or (3), you can use "High-speed binary retract function", but you can't use "High-speed binary skip function".
- In case that you store Learning data and recycle it, refer to **7.2 Learning data transmission function**.

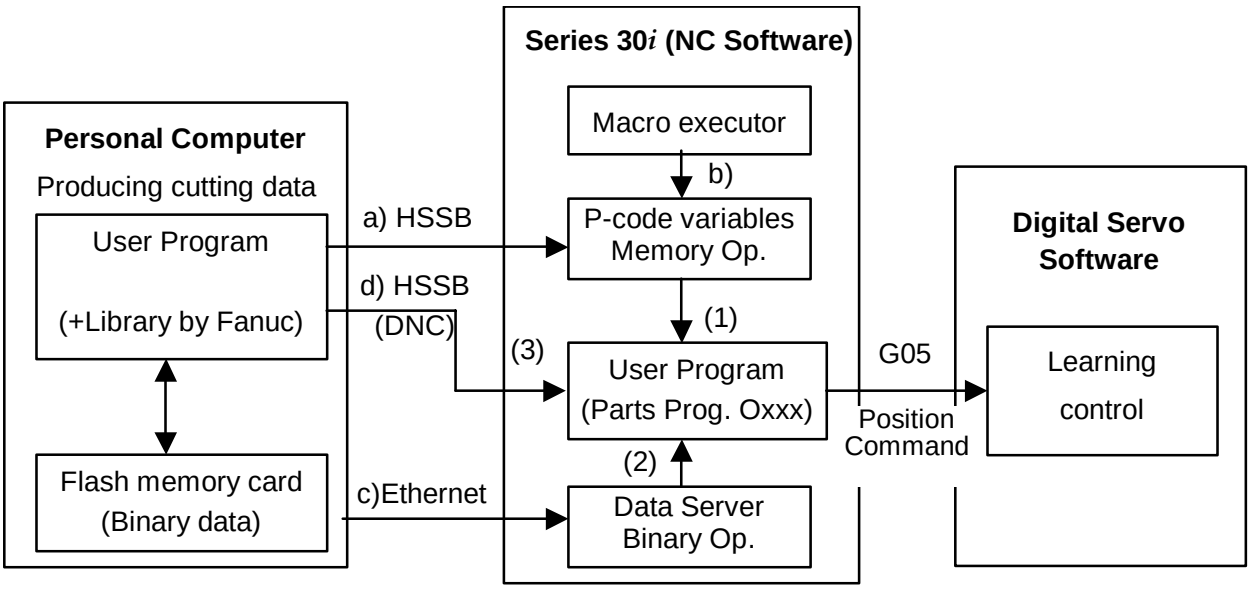


Fig. 2-1 System configuration selection

3. Application example

3.1 Lead cutting machine

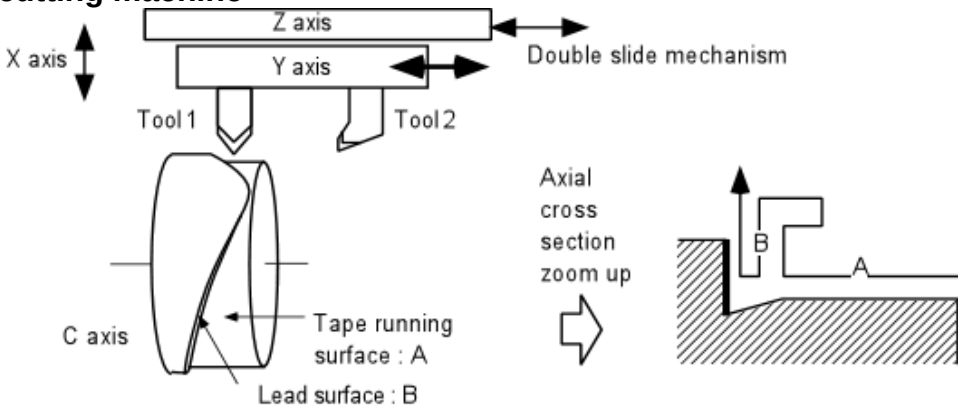


Fig. 3.1.1 Configuration example of Lead Machining Tool

* Cutting Sequence

(1) The surface running tape is finished synchronizing with C-axis rotation, moving the tool 1 back and forth along the Y-axis. By feeding the tool along the Z-axis, the lead surface is gradually cut deeper. (Process A)

(2) To finish the lead surface, the tool retreats along the X-axis temporarily and moves along the Z-axis (offset). And the tool is changed to tool 2. Then, the movement of Y-axis and C-axis don't stop.

(3) The tool 2 is fed along the X-axis and the lead surface is finished. (Process B)

(4) Both Y-axis and C-axis use either **Suspension mode** or **Continuation mode** of Learning control.

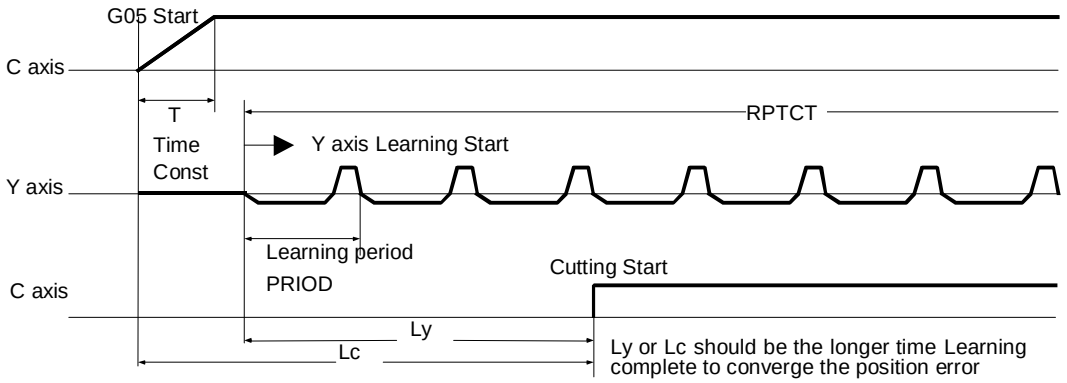


Fig. 3.1.2 Axes Movement of the velocity at the start

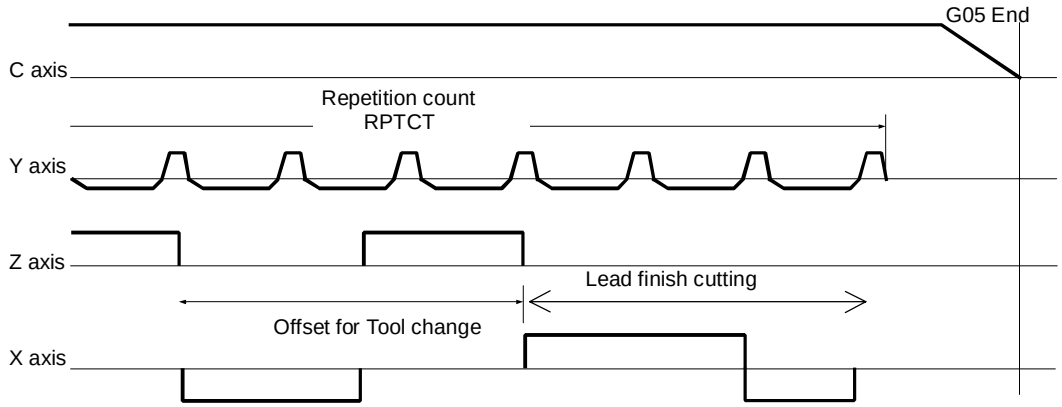


Fig. 3.1.3 Axes Movement of the velocity at End

3.2 Piston Lathe

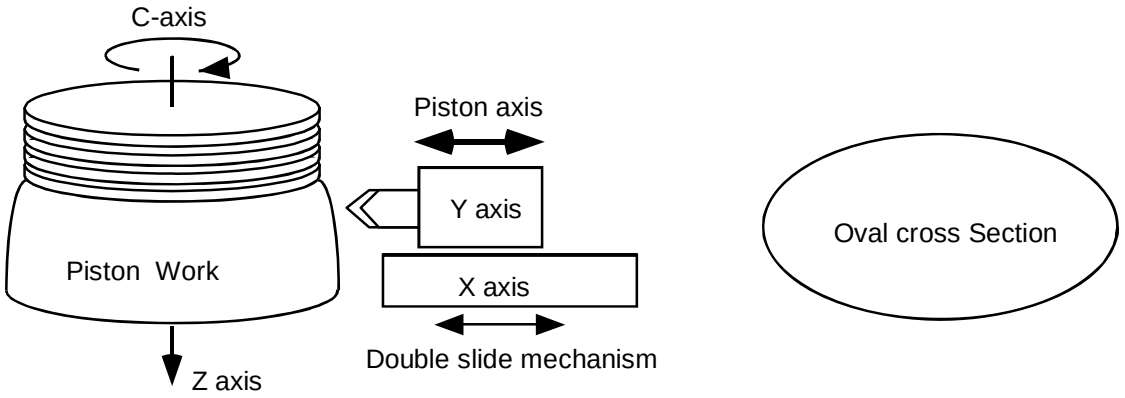


Fig. 3.2.1 Configuration example of piston lathe

* Cutting Sequence

(1) The piston outline is finished by rotating C-axis moving the tool back / forth along Y-axis. By feeding the tool along the Z-axis, the cylindrical piston is gradually cut.

(2) Both Y-axis and C-axis are used either **Suspension mode** or **Continuation mode** of Learning control. When the command of Y-axis gradually changes, Y-axis should be used **Continuation mode** of Preview repetitive control. If the changing rate of the command is small, you might be able to get the sufficient accuracy with **Continuation mode** only.

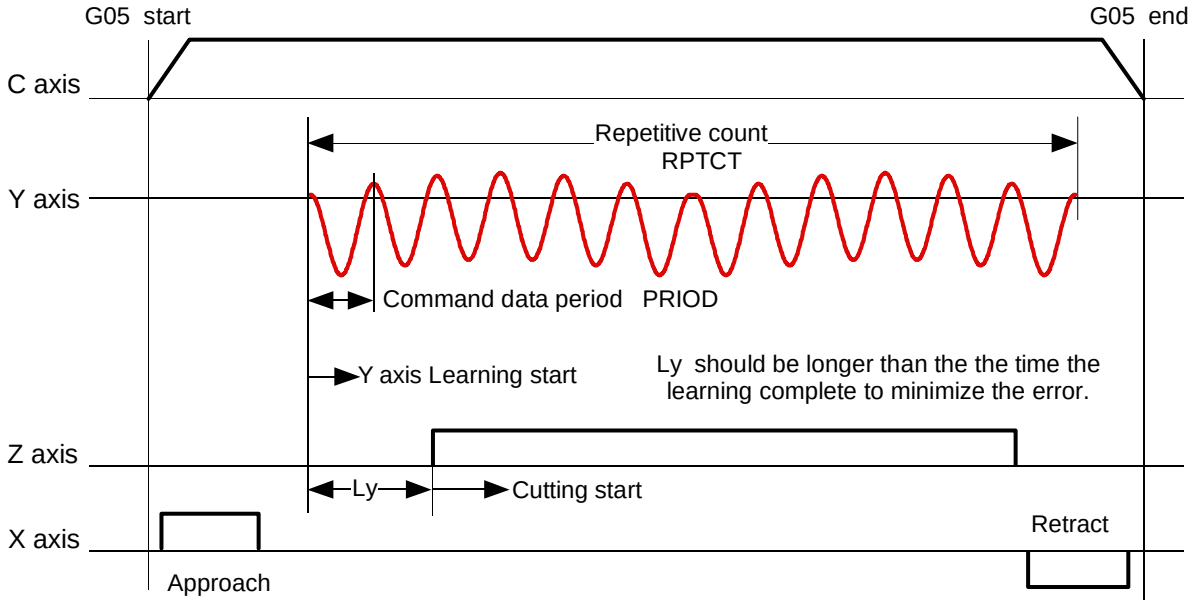


Fig. 3.2.2 Movement of the tool along each axis when processing

3.3 Cam Grinding Machine

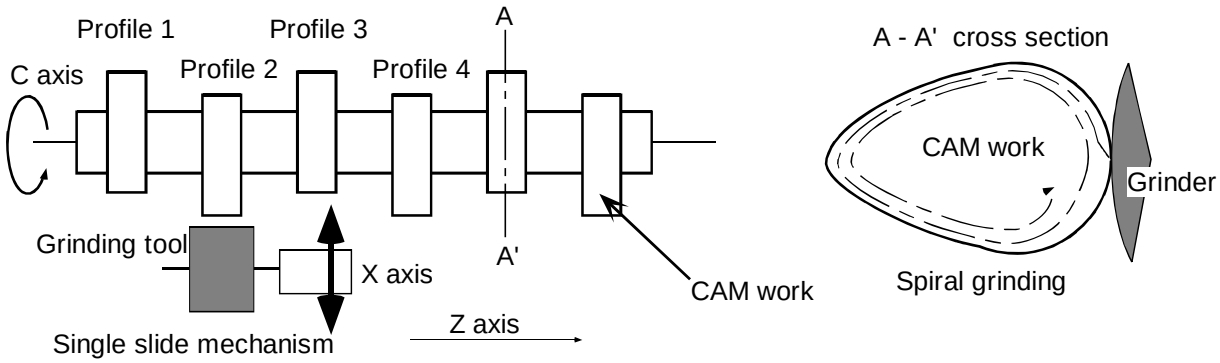


Fig. 3.3.1 Example of Configuration of Cam Grinding Machine.

* Grinding Sequence

(1) The cam form is ground by synchronizing with C-axis rotation moving grinder back / forth along X-axis.

(2) Each profile is processed with High-speed cutting (G05), but G05 stops while Z-axis moves to next profile.

In case of the profile processed by many repetitive cycles.

(3) Set one rotation of C-axis as Learning period.

(4) Though the finishing can get down the rotation speed of C-axis, not to change the rotation speed of C-axis (L1=L2) is recommended from the precision point of view.

(5) The rotation speed of C-axis can vary within one rotation of C-axis. There might be the special machine such as the crank pin grinding required very high accuracy. As far as grinding technology allows, the constant C-axis speed within one rotation is preferable for the application of high accuracy.

(6) Both X-axis and C-axis are used **Compensation data continuation mode** of the Preview repetitive control.

In case of the profile processed by a few repetitive cycles.

(3) Set the total C-axis rotation involving Approach as Learning period.

(4) **Compensation data continuation mode** of the Preview repetitive control is used with Repetition count set to one.

(5) You need to repeat about ten times trial of G05 till the sufficient convergence of the error achieved.

(6) If you don't want to renew the compensation data at each grinding, you have to set **compensation data suspension mode** active and Repetition count to zero.

(7) Make sure to set Shock reducing counter (SHKRDC) effective.

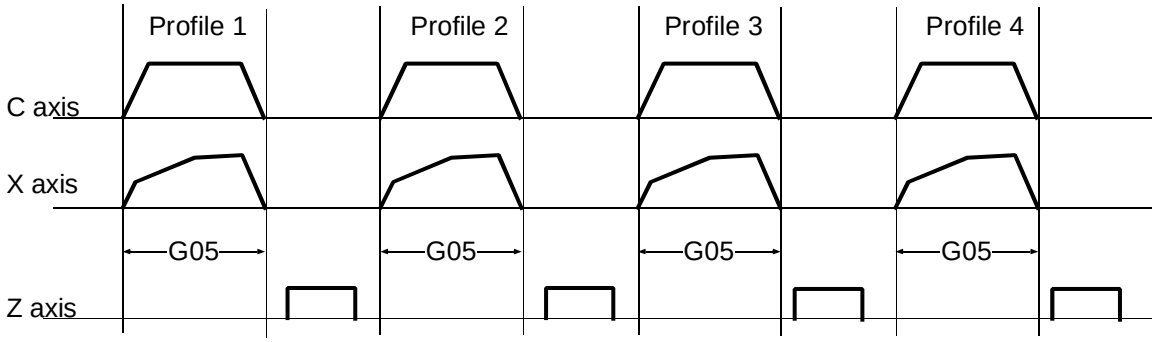
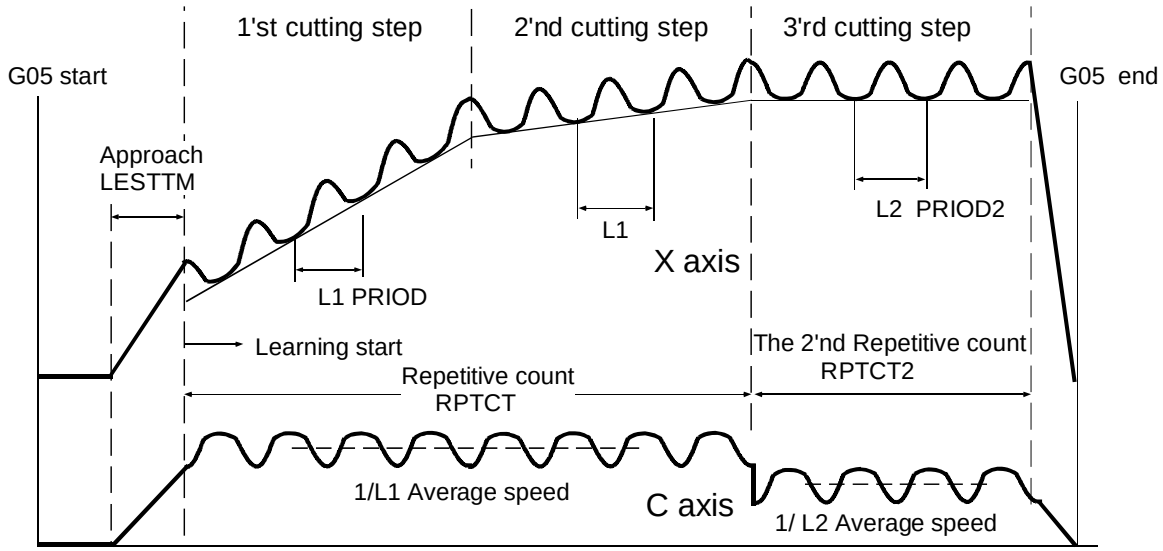
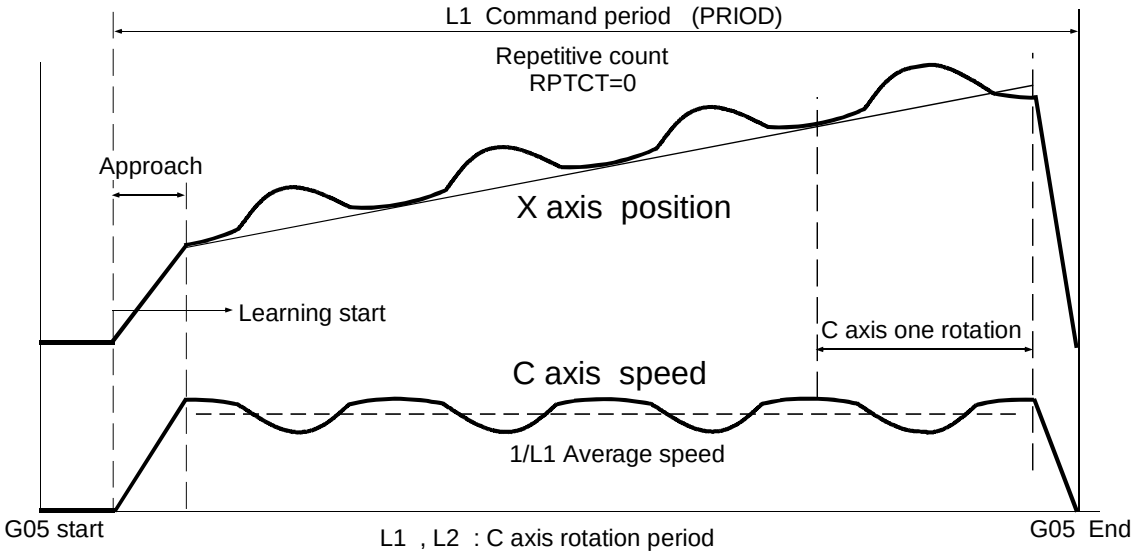


Fig. 3.3.2 Movement of the Tool along each Axis.



L1 , L2 : C axis rotation period

Fig. 3.3.3 Cutting Chart (when profile 1)



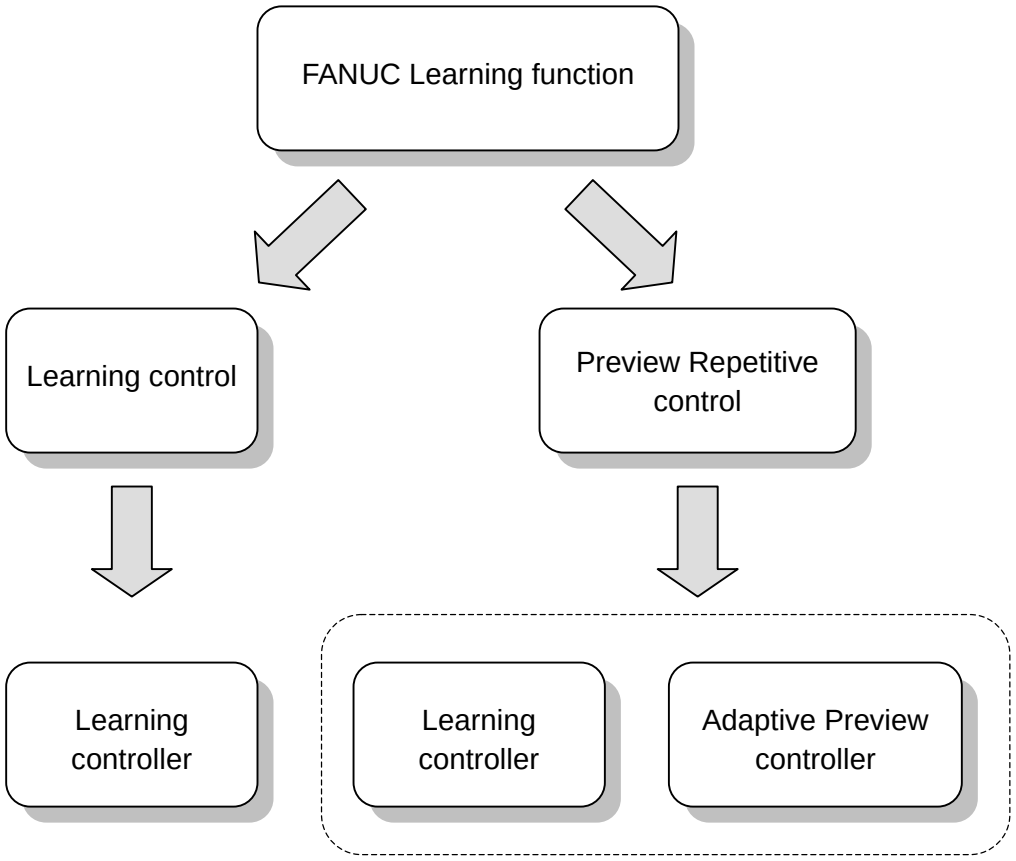
L1 , L2 : C axis rotation period

Fig. 3.3.4 Cutting Chart 2 (Profile 1)

				Title	90D3 / 90E3 Learning Control Operator's Manual
				Draw No.	A - 63639E – 108
01	'05.04.20	N.Sonoda	Newly designed	FANUC LTD	Sheet 09 / 064
Edit	Date	Design	Description		

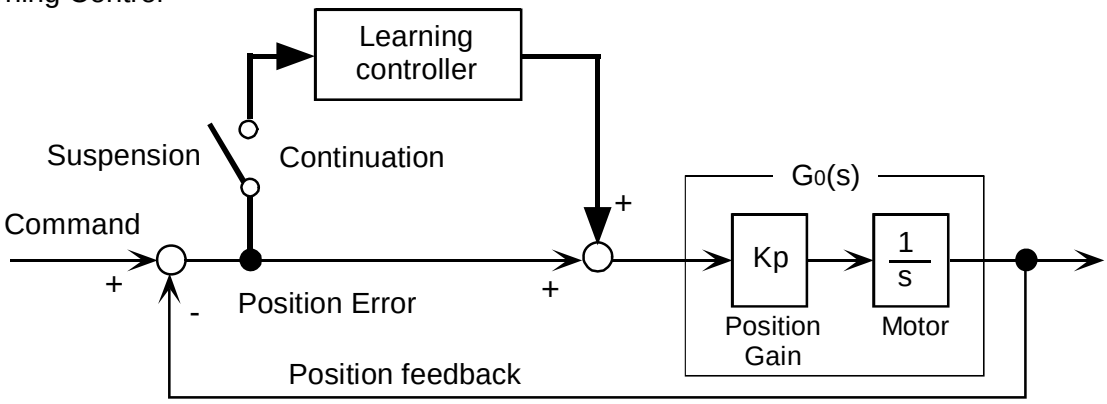
4. Explanation of Learning Control

4.1 Summary of Learning Control



- What is “Learning Function” ?
  It is a function for realizing high-speed and high-precision cutting by using Learning Control (Repetitive Control) or Preview Repetitive Control. Preview Repetitive control is the superset for Learning control. So one of each is necessary not both to set ordering.
- Configuration of Learning function
  Learning Control (Repetitive Control) is realized by Learning controller. And Preview Repetitive Control is realized by combination with Learning controller and Adaptive Preview controller.
- Feature of Control
  Learning controller minimizes the position error by learning the repetitive command of specific period or the disturbance synchronized with learning period. And Adaptive Preview controller follows rapidly the command by means of doing the suitable feed-forward control decided by Adaptive control.
- How does “Preview Repetitive control” apply?
  The convergence of error (Learning speed) by Preview Repetitive control is faster than that by only Learning controller. Learning control can be even applied for the case that the periodic command gradually changes the shape. If the change of the shape is comparatively rapid and large, you should adopt Preview Repetitive control.

4.2 Learning Control



[Merit]

- Replacing the mechanical cam tracing method with the electric master cam.
- Minimized position error for repetitive command with specified period.
- Ability to remove periodical disturbance synchronized with command period.

[Algorithm]

Learning control starts from non-zero command in G05.

a) Learning controller takes Position error within one period to create the compensation data called **Learning data**.

b) The new Learning data is compared with old one, which sampled in previous period.

c) The new Learning data is renewed to reduce the position error.

d) The new Learning data within one period is kept into memory in Learning controller as the old one.

By repeating from a) to d), Learning data continue to renew itself in order to minimize position error.

[Mode]

Select one from four below mode fitted with your application.

(1) **Suspension mode**

For each High-speed cutting (G05), Learning data continues to renew up to Learning suspension count BRCT parameter. Then the learning is suspended and the last Learning data is used for control without the renewal. BRCT is set for the position error to converge by the learning. This mode is usually used on the lead cutting machine. When BRCT is zero, Servo does not renewal the Learning memory.

(2) **Continuation mode**

While High-speed cutting is executed, Learning data renew itself up to the end. This mode is used on the command gradually changes, though the period is constant. This mode is normally used on the piston lathe.

(3) **Compensation data suspension mode**

This mode is similar to Suspension mode for the first High-speed cutting after the power is turned on. The second and subsequent High-speed cutting is performed using Learning data created by Learning at the last G05. The created Learning data isn't deleted unless the power is turned off. This mode is normally used for the cam grinding machine, which the shortening of cycle time is required, or in case that the command doesn't include the cutting feed such as double slide mechanism.

(4) **Compensation data continuation mode**

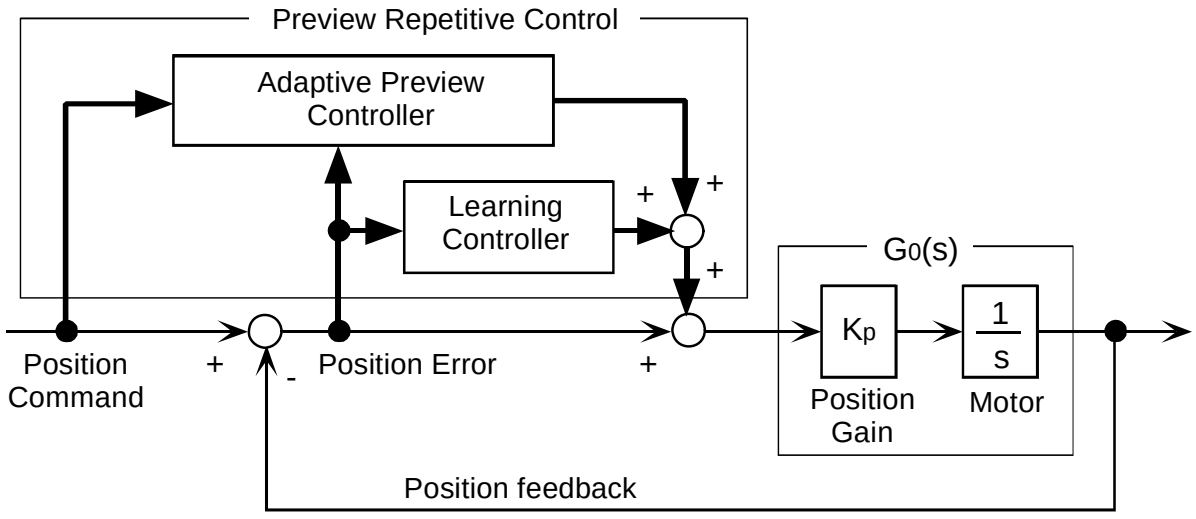
This mode is similar to Continuation mode for the first high-speed cutting after the power is turned on. The second and subsequent the High-speed cutting is performed using Learning data created by learning at the last G05. The created Learning data isn't deleted unless the power is turned off. This mode is normally

used for the cam grinding machine, which the shortening of cycle time is required, or the command within one profile gradually change due to cutting feed such as single slide mechanism.

Note

Compensation data mode means that Learning data isn't clear at the end of G05. Both Suspension and Continuation mode clear it every time at the end of G05. And it takes some times to clear. So when you execute two or more successive G05, it might be necessary to add G04 to wait the time after G05 before starting the next G05. Refer to 7.2.2 processing flow for the time.

4.3 Preview Repetitive Control



[Merit]

- Learning controller decides the final error, while Adaptive preview controller accelerates to decrease the error.
- Adaptive preview control is effective for a case that Command gradually changes.
- Adaptive preview control is effective for the application to change the reiterated command period at halfway through G05.

[Algorithm]

- Preview repetitive control is realized by combination with Learning controller and Adaptive Preview controller.
- Adaptive preview control does the suitable feed-forward control by using Adaptive control.
- Feed-forward coefficients are calculated so as to reduce the position error by utilizing the repetition of command.
- As this result, position error decreases without Learning controller. The position error due to disturbance is gotten rid of by Learning controller of Preview repetitive control, because Adaptive Preview controller is ineffective to disturbance.
- Feed-forward coefficients are decided in **Adaptive mode** of Adaptive preview control. During this time, Learning control is disabled automatically.
- The decided coefficients are transmitted to CNC for the purpose of holding it even at Power off. It is called **Transmitting mode** of Adaptive preview control.
- You should process in **Fix mode** of Adaptive preview control in which the coefficients is not renewed. Then Learning control gets valid.

5. Servo parameters

5.1 Setting parameters

5.1.1 Setting CNC parameters

The following explanation is CNC parameters setting related to High-speed Cutting (G05).
For the detail, refer to Parameter Manual of CNC.

(1) Set the following parameter.

- No.1004 (Bit type) B1=1, B0=0 (IS-C : 0.1μm setting).
- No.1820 (Word axis type) set to CMR.
- No.1825 (Word axis type) set to Position Loop Gain.
- No.7501#6 - #4 (Bit type) set to Interpolated period (ITP) for G05.

  111 : 0.5msec, 011 : 1msec
  001 : 2msec, 010 : 4msec
- No.7501#7 (Bit axis type) set to 1. (Detection function for ITP delay)
- No.7502#0 (Bit axis type) set to 0. (Acceleration / Deceleration isn't used during G05)
- No.7505#1 (Bit axis type) set the magnification for G05 data.

  0 : x 1 times (Usual case)
  1 : x 10 times (Special case described below)

  In case that the setting unit of a rotary is 0.0001 degree and G05 data exceeds 1 word (32767).
- No.7510 (Word type) set to maximum control axes during G05.

Note	• The interpolated period 0.25 msec. is unavailable so far due to CNC software condition. • All axes commanded by High-speed Cutting must be allocated to stuff the first and subsequent CNC axis without Not-High-speed cutting mixed.

(2) Set the following parameter to allocate each axis

- No.1023 (Word axis type) set to servo axis number.
- Learning axis must be allocated to an odd number axis (1st or 3rd or 5th axis).
- The subsequent even axis is available as the normal axis.

(Example 1) In the following configuration, set 1, 2, -1 and 3 for No.1023.

Axis name	Servo axis number
X axis	1st axis (Learning axis)
Z axis	2nd axis (normal axis)
C axis	Cs axis (Spindle)
Y axis	3rd axis (Learning axis)

Note	If No.1023 is set to –128, it gets dummy axis.

(Example 2) In the following configuration with αis 300 or αis 500, set 1, 3, 5 and 6 for No.1023.

Axis name	Servo axis number
X axis	1st axis (Learning axis)
Z axis	3rd axis (Learning axis)
C_1 axis	5th axis (Tandem axis)
C_2 axis	6th axis (High speed axis)

Note
- αis 300 or αis 500 must be set to Tandem axis. This motor occupies two servo axes that are the odd and the subsequent even number.
- You must set No.1817#6 of both main and sub axes to 1. (Tandem control is the software option.)
- You must set No.2018#7 of the sub axis to 1.

5.1.2 FSSB setting

You should think the allocation of axis number (No.1023) and amplifier number (No.14340-) because the connection from CNC to amplifier is serially linked by optical cable (FSSB2 interface).
Refer to the following example.

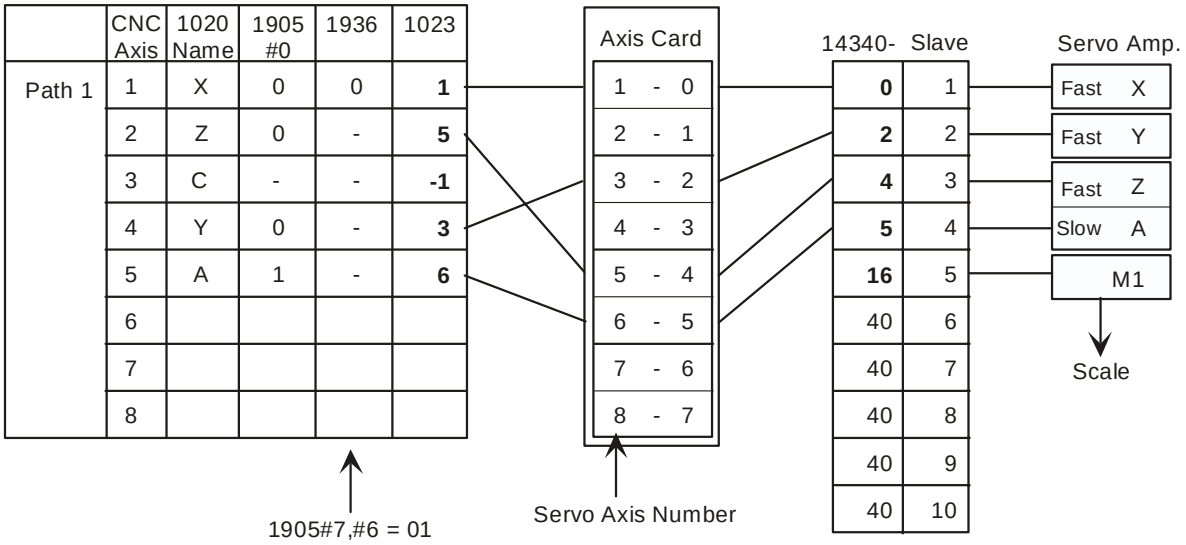


Fig. 5.1.2 FSSB2 setting example

Note

If you made mistake about FSSB setting, you have to pull out FSSB cable and modify FSSB setting.

In case of using HRV3 or HRV4 control, refer to the item of servo HRV3, HRV4 control in "FANUC AC SERVO MOTOR α *is* / α *i* / β *is* series Parameter Manual". Be careful in the following items.

1) Hardware (Servo axis control card, Servo Amplifier, Outer detector I/F unit)
2) Software (CNC software, Servo software)
3) Parameters setting

5.1.3 Setting servo parameters

For the detail, refer to "FANUC AC SERVO MOTOR α *is* / α *i* / β *is* series Parameter Manual".

You should set it for each axis because all servo parameters (No.2000 - No.2269) are axis type.

(1) Set the following parameters fitted each motor and machine.

- No.2000#1 - #0 set to 00.
- No.2001#7 - #0 set to 00000000.
- No.2020 set to the Motor ID number. (from 251)
- No.2021 set to Load Inertia ratio.
- No.2022 set to the motor rotary direction. (111 or –111)
- No.2023 set to 8192.
- No.2024 set to 12500.
- No.2084 set to SDMR1.
- No.2085 set to SDMR2.

(Example 1) Lead pitch of ball screw is 12mm/rev. (detective unit 0.1μm)

$$\frac{120000}{1000000} = \frac{12}{100} \quad \rightarrow \quad \frac{\text{SDMR1}}{\text{SDMR2}}$$

(Example 2) Rotary axis, 4/10000 degree detective unit and 900000 pulses/rev

$$\frac{900000}{1000000} = \frac{90}{100} \quad \rightarrow \quad \frac{\text{SDMR1}}{\text{SDMR2}}$$

(Example 3) Linear motor, LS486 (20μm pitch) and 0.1μm detective unit

$$\frac{5 / 0.1}{128 \times (20 / 20)} = \frac{50}{128} \quad \rightarrow \quad \frac{\text{SDMR1}}{\text{SDMR2}}$$

(Example 4) Full-closed rotary axis, Outer serial rotary encoder (α1000),
1/1000 degree detective unit and 360000 pulses/rev, gear ratio 1/20

$$\frac{360000}{1000000} = \frac{36}{100} \quad \rightarrow \quad \frac{\text{SDMR1}}{\text{SDMR2}}$$

No.2024 = 12500 / 20 = 625

(Example 5) Full-closed linear axis, linear scale (4μm pitch) + High precision serial output circuit (A860-0333-T501, 512 division), Ball screw 8mm/rev, 0.1μm detective unit

Feedback pulses before F.F.G per one motor rotation = 8mm / (4μm / 512) =1,024,000 P/rev

$$\frac{800000}{10240000} = \frac{80}{1024} \quad \rightarrow \frac{\text{SDMR1}}{\text{SDMR2}}$$

No.2024 = 1024,000 / <u>100</u> = 10,240

No.2185 = <u>100</u>

(Example 6) Full-closed linear axis, linear scale (4μm pitch) + High precision serial output circuit H (A860-0333-T701, 2048 division), Ball screw 8mm/rev, 0.1μm detective unit

Feedback pulses before F.F.G per one motor rotation = 8mm / (4μm / 2048) =4,096,000 P/rev

$$\frac{4\ [\mu\text{m}]/2048}{0.1\ [\mu\text{m}]} = \frac{40}{2048} = \frac{5}{256} \quad \rightarrow \frac{\text{SDMR1}}{\text{SDMR2}}$$

No.2024 = 4096000 / <u>400</u> = 10,240

No.2185 = <u>400</u>

(2) Turn off the power supply, then turn it on. (Auto loading of parameter for each motor)

Note

1) In case of Learning axis, set the following parameters and turn off / on the power supply.
   - No.2019#6 set to 1 for Learning axis
   - No.2019#5 set to 1 for Preview repetitive axis.

2) In case of Linear motor, set the following parameters and turn off / on the power supply.
   In detail, refer to "FANUC AC SERVO MOTOR α *is* / α *i* / β *is* series Parameter Manual".
   Example) Linear scale (LS486, 20μm pitch), L*i*s6000B2 (magnetic pitch 60mm)
   - No.2010#2 set to 1
   - No.2023 set to 5,000
   - No.2024 set to 16,000
   - No.2112 set o 512∗(60/20)=1,536

5.1.4 Caution for servo parameter setting (for transferring from series16*i*)

The parameter number for Learning control is different between series 16*i* and series 30*i*. Refer to **Appendix 6. Parameter number difference between series 16*i* and 30*i*.**

Note Learning servo software 90D3 series is fully upper compatible with standard servo software 90D0 series. Learning parameters for 90D3 series have been moved because the part of Leaning parameters for conventional 90B3, 90B7 series have overlapped with parameters of other function for standard 90B0 series.

Velocity loop proportional high-speed processing function performs velocity proportional routine with high-speed sampling. The part of parameters in conventional 90B3, 90B7 series had to be set by manual depending on sampling rate. But these parameters in 90D3 series are automatically set the converted parameter to inside parameter. In order to keep compatibility with conventional parameter, the compatible bit parameter (No.2227#2) is prepared.

Function	90B3, 90B7 series	90D3 series		Remark
		No.2227#2=0	No.2227#2=1	
Tcmd filter No.2067=0	Invalid	Valid (300Hz)	Invalid	When No.2017#7=1
Tcmd filter No.2067	Manual setting	Automatic converting	Manual setting	When No.2017#7=1
Acceleration feedback No.2066	Available	Unavailable	Available	When No.2017#7=1
Integral gain PK1V No.2043	Manual setting	Automatic converting	Manual setting	
PK4V No.2044	Manual setting	Automatic converting	Manual setting	

5.2 Setting High gain parameter

In case of using Learning control for Cam grinder etc, if the position error does not converge due to the influence of big disturbance, you apply Learning HRV2 control for the High gain by the following procedure. Refer to "**Appendix 3. Parameter table for Learning control".**

Learning HRV2 control means HRV2 control with velocity loop period 0.5msec.

(1) Set the standard parameter with referring to "**5.1.3 Setting servo parameters**".

(2) Set the following parameters with the emergency ON (*ESP ON),

- No.1825 set to 6000. (Position Gain)
- No.2003#3 set to 1. (PI control)
- No.2004 set to xx1x0001. (Don't change "x" bit)
- No.2019#6 or #5 set to 1. (Learning control axis)
- No.2044 set to twice of HRV1 standard. (PK2V)

(3) Set Learning control parameters.

- No.2512 set to 200. (Frequency band of the low pass filter)
- No.2526 set to 10. (Maximum order of Gx)
- No.2527 set to 0. (Minimum order of Gx)
- No.2528 set to 64. (Coefficient 1)
- No.2529 set to –32. (Coefficient 2)

(4) Turn Off / ON the power supply.

(5) Set the other Learning control parameter if necessary.

(6) If Adaptive preview control is used, you should adapt the feed-forward coefficients according to "**6.3 Adaptive Method**".

Note

Servo axes existing on the same DSP must be set to the same sampling rate. Therefore all these axes are required to set No.2004 to the above value. For example, the sequent even axis with Learning axis must be set No.2004 to the same value as Learning axis.

Be careful that the parameter number for learning control is different from series 16*i*.

High gain setting of series 16*i* is similar to Learning HRV2 control of series 30*i*.

In Learning HRV2 control, if the position error exceeds 30,000 pulses without Learning control, it is necessary to apply either Feed-forward control or Adaptive preview control in order to suppress the error to less than 30,000 pulses.
Please use No.2092 as the coefficient for Feed-forward control.

5.3 Setting Learning HRV3, HRV4 control

Servo HRV3, HRV4 control is available with Learning series 90D3. The setting bases on standard series, refer to "FANUC AC SERVO MOTOR αis / αi / βis series Parameter Manual" (B-65270E). The following describes about the special points in Learning series.

5.3.1 Setting Learning HRV3 control

Set Learning HRV2 control according to "**5.2 Setting High gain parameter**".

No.2013#0 set to 1. (Servo HRV3 control)
No.2334 set to 150. (Current loop gain magnification)
No.2335 set from 100 to 400. (Velocity loop gain magnification)
No.2283#0 set to 1. (High-speed HRV current control with cutting mode)

5.3.2 Setting Learning HRV4 control

Set Learning HRV2 control according to "**5.2 Setting High gain parameter**".

No.2004 set to xx0x0011. (Don't change "x" bit)
No.2014#0 set to 1. (Servo HRV4 control)
No.2040 set to 1.5 times of HRV2 standard.
No.2041 set to 1.5 times of HRV2 standard.
No.2334 set to 200. (Current loop gain magnification)
No.2335 set from 100 to 400. (Velocity loop gain magnification)
No.2283#0 set to 1. (High-speed HRV current control with cutting mode)

Note

This setting is different from standard HRV3, HRV4 setting, and doesn't require the NC program "G05.4 Q1" which changes the mode into High-speed HRV current control only during cutting mode (G01).

Fixed HRV control bit No.2271# 0 set to 1 in order to be High-speed HRV current control mode at all time regardless of cutting mode (G01) etc.

5.3.3 Setting Learning HRV3 control for Piston lathe, Lead cutting

Piston axis or Turner axis is set parameters referring to **Appendix 3. Parameter table for Learning control**. Take care of the parameters No.2003#0 = 1 and No.2004 = 11111010.

Note

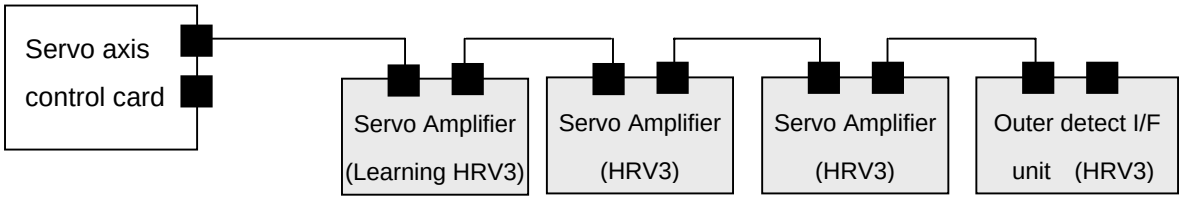
This setting is different from standard HRV3 setting, which does not require the NC program "G05.4 Q1".

This setting is fixed in the high-speed HRV current control mode with not only cutting mode (G01) but also other mode.

5.3.4 FSSB connection

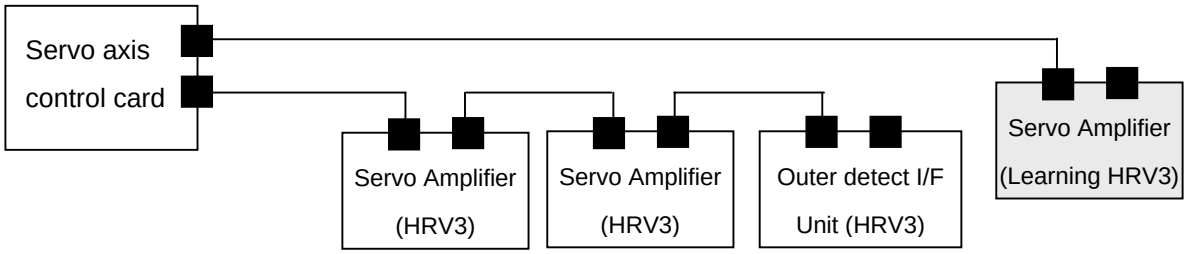
(1) Case of one FSSB path

All axes connected with one FSSB path require setting to the same HRV control. Therefore, if Learning HRV3 control is applied in one axis at least, other all axes require Servo HRV3 control.

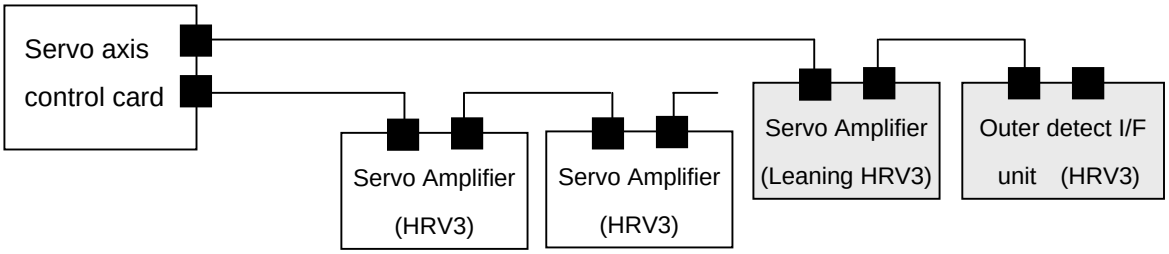


(2) Case of two FSSB paths

Even if two FSSB path is used, all axes connected with each FSSB path require setting to the same HRV control. Therefore, if Learning HRV3 control is applied in one axis at least, other all axes that include another FSSB path require Servo HRV3 control.



If Learning axis is full-closed system, outer detection I/F unit must be connected with the same path as Learning axis.



There is the following restriction with regard to the possible number of unit connecting with the same FSSB path.

Control	Maximum number of Amplifier / Outer detection unit
HRV2	16 / 2
HRV3	10 / 2
HRV4	4 / 1

5.4 Servo parameters List

The following parameters are for FS30*i*. The shaded parameters are detailed in this manual.

	B7	B6	B5	B4	B3	B2	B1	B0
2000				PGEX	PRMC		DGPR	PLC0
2003	VOFS	OVSC	BLEN	NPSP	PIEN	OBEN	TGAL	TIA1
2004	DLY1	DLY0	TIB1	DLY2	TRW1	TRW0	TIB0	TIA0
2005	SFCM	BRKC				36RPC	FEED	
2010					BLTE	LINE	TLIMCG	
2013	APTG	VFBH						HRV3
2014								HRV4
2017	PK25	OVCR		HTNG				DBST
2018	PFBCPY							
2019		SLEN	INVSYS		LBUFEX		TANDMP	
2200	PK2VSF			PFBSFT				OVRNSP
2201			VOCECM				RUNLVL	CROF
2203	RPL246		TCMDX4			1/2PI		
2226	MEMCL	PRFCLR						QUCKST
2227			ANGLRN	ANGREF		GOKAN		
2228	VFB2MS	FRQ	VFB500	VFB1MS		HSBLC		SYSLRN
2229	TAWAMI	STPRED	HSSATU			RCNEG	TIMADJ	ABSEN
2271				TCAVF				HRV3AL
2283								NOG54
2442			ADERSL	VCMDCL	UNTSL	TRASMT	ADAPT	

2443		ICM		LCON	EXGX	MSCHK		LSTP
2444								
2445								

2066		Acceleration feedback gain (negative value)
2067		Torque command filter
2112		AMR1 conversion coefficient
2139	AMROFS	AMR offset
2156		Torque command filter (at cutting)
2165		Maximum amplifier current
2185	PSMPYL	Position feedback pulses conversion coefficient
2302		OVC magnification for HRV3
2334		Current gain magnification (HRV3)
2335		Velocity gain magnification (HRV3)
2510	PRFALL	Total profile number
2511	PRFNO	Profile number
2512	FBND	Frequency band of the low pass filter (Hz)
2513	BRCT	Learning suspension cycle (cycle)
2514	LESTTM	Learning start time
2515	STPRPT	Step repetition number
2516	RPTCT	1st repetition count (cycle)
2517	PRIOD	1st Learning period (msec)

2518	RPTCT2	2nd repetition count (cycle)
2519	PRIOD2	2nd Learning period (msec)
2520	RPTCT3	3rd repetition count (cycle)
2521	PRIOD3	3rd Learning period (msec)
2522	RPTCT4	4th repetition count (cycle)
2523	PRIOD4	4th Learning period (msec)
2524	RPTCT5	5th repetition count (cycle)
2525	PRIOD5	5th Learning period (msec)
2526	GODMX	Maximum order of Gx
2527	GODMN	Minimum order of Gx
2528	GCOEF / EXGXK1	Max. coefficient of Gx / Coefficient 1 of expanded Gx
2529	EXGXK2	Min. coefficient of Gx / Coefficient 2 of expanded Gx
2530	EXGXK3	Coefficient 3 of expanded Gx
2531	EXGXK4	Coefficient 4 of expanded Gx
2532	EXGXK5	Coefficient 5 of expanded Gx
2533	EXGXK6	Coefficient 6 of expanded Gx
2534	SHKRDC	Shock reducing counter
2535	SFTTH1	Manual thinning count
2536	TAWA1L	Torsion compensation coefficient during G05
2541	MSCKLV	Maximum speed check
2543	ADPCE	Adaptive coefficient
2544	FORW1	Feed forward coefficient W_1

2545	FORW2	Feed forward coefficient W_2
2546	FORW3	Feed forward coefficient W_3
2547	FORW4	Feed forward coefficient W_4
2548	FORW5	Feed forward coefficient W_5
2549	FORW6	Feed forward coefficient W_6
2550	LERRLV	Error monitoring level (detection unit)
2551	ERMOST	Error monitoring start time (msec.)
2552	ERMOFN	Error monitoring finish time (msec.)

5.5 Servo parameter detail

If not necessary, don't change the standard parameters of Auto loading by motor ID.
In case of specifying series and edition, you can use the function from that edition or later.

2013		APTG	VFBH						HRV3

HRV3 Servo HRV3 control is
1 : useful.
0 : not useful. (normal)
(Note) After setting Servo HRV2 control, you must set this bit on.

VFBH Velocity feedback is
1 : High speed processing
0 : Normal speed processing

2014									HRV4

HRV4 Servo HRV4 control is
1 : useful.
0 : not useful. (normal)
(Note) After setting Servo HRV2 control, you must set this bit on.

2017		PK2V25	OVCR						DBST

PK2V25 Velocity loop proportional high-speed processing function is
1 : useful.
0 : not useful. (normal)

2018		PFBC							REVS

PFBC Motor feedback is taken from (**Sub axis only**)
1 : L-axis.
0 : M-axis. (standard)
(Note) In case of αis300 or αis500 or connected Linear motor, set this bit to 1 with Tandem control.

2200			EX2V						OVRNSP

EX2V Velocity proportional gain weight
1 : 1/4
0 : Normal setting
(Note) When parameter alarm is caused by large Load inertia ratio, set to 1.

OVRNSP Detecting of runaway in full-closed system is
1 : not useful.
0 : useful.
(Note) In case that rotation direction is fixed in initial setting, set this bit 1.

2201								RUNLVL	CROF

CROF At emergency stop, current offset is
1 : re-taken in.
0 : not re-taken in. (standard)

2227				ANGLNG	SNGREF		GOKAN	ERRCHK	PARTLE

GOKAN When the velocity loop proportional high-speed processing is applied,
1 : servo characteristic is compatible with 90B3 series
0 : servo characteristic is compatible with 90D0 series
(Note) It is called Compatible bit parameter.

2228		FRQ				HSBLC		SYSLRN
2229	TAWAMI	STPRED				RCNEG	TIMADJ	ABSEN
2271				TCAVE				HRV3AL

TCAVE Average torque is
1 : outputted (Note) You must set 1 for No.2208#7 at same time.
0 : not outputted
HRV3AL
1 : Always enabling high-speed HRV current control without G05.4

2283								NOG54

NOG54 High-speed HRV current control is
1 : executed with G01
0 : executed with both G01 and G05.4

2066	K2AUX Acceleration feedback gain (negative value)

Note

Normally Acceleration feedback function is unavailable when Velocity loop proportional high-speed processing function is valid. But it is available if Compatible bit (No.2227#2) is set to 1. Acceleration feedback function is kept compatible with 90B3 series by this bit.

2067	FILTER	Torque command filter coefficient (for cutting)
2156	FILTER	Torque command filter coefficient (for rapid traverse)

Standard : 0

Set by the following expression. fc : Cut-off frequency [Hz], τ : Sampling time [sec.]

(Setting value) = $4096 \times \exp(-2\pi \times fc \times \tau)$

(Example 1) Case of normal axis (τ = 1msec.) and fc = 300 [Hz]

No.2067 = $4096 \times \exp(-2\pi \times 300 \times 0.001) = 622$

(Example 2) Case of Learning HRV2 (τ = 0.5msec), No.2227#2=1 and fc = 300 [Hz]

No.2067 = $4096 \times \exp(-2\pi \times 200 \times 0.0005) = 1596$

(Example 3) Case of Learning HRV2, No.2227#2=1, Velocity loop proportional high-speed processing function (τ = 125μsec.) and fc = 300 [Hz]

No.2067 = $4096 \times \exp(-2\pi \times 300 \times 0.000125) = 3236$

	Normal axis (τ = 1ms)	No.2227#2=1: High Gain axis (τ = 0.5ms)	No.2227#2=1: No.74 or No.75 (τ = 125μs)
80Hz	2478	3186	3847
100Hz	2185	2992	3787
120Hz	1927	2810	3728
140Hz	1700	2638	3669
160Hz	1499	2478	3612
180Hz	1322	2327	3556
200Hz	1166	2185	3501
250Hz	851	1868	3366
300Hz	622	1596	3236
350Hz	454	1364	3112
400Hz	332	1166	2992

Note

1) You select above normal axis setting in case of Learning HRV2 control and N2227#2=0.
2) If Velocity loop proportional high-speed processing function is valid, Torque command filter is inside set to 300Hz regardless of No.2067=0. In this case, it is possible to make invalid by the following setting.
   HRV1 and HRV2 No.2067=-4157
   HRV3 and HRV4 No.2067=-11348

6. Learning Control function

6.1 Learning Control parameters

2019	DPFBCT	SLEN	INSYS	SUPRSY	LEBFEX		TANDEC	

SLEN Learning control (Option) is
1 : Available.
0 : Not available.

2442		STPRED	ADERSL	VCMDCL	UNTSL	TRASMT	ADAPT	
2443		ICM		LCON	EXGX	MSCHK		LSTP

ICM Compensation data mode is
1 : Available.
0 : Not available.

LCON Learning control is
1 : Suspension mode.
0 : Continuation mode.

ICM	LCON	Learning Mode
0	0	Suspension
0	1	Continuation
1	0	Compensation data suspension
1	1	Compensation data continuation

EXGX Dynamic characteristic compensation (Gx) is
1 : Expanded Gx.
0 : Normal Gx. (standard)

(Note) Expanded Gx makes the compensation of high precision. According to Gx setting, refer to **Appendix 3. Parameter table for Learning Control**.

UNTSL The unit of command period (No.2517, No.2519, etc) and Learning starting time (No.2514) and Shock reducing counter (No.2542) is
1 : data number. (command period (msec) / Velocity period (msec))
0 : msec. (standard)

(Example) When UNTSL = 1, you must set No.2542 to 125 in case that Command period is 62.5msec and Velocity loop is 1msec.

2226	MEMCL	PRFCLR		LCT2WD	FFEXP	SVGDCG		QUCKST

MEMCLR At G05 finish, Learning memory is
1 : clear in .
0 : clear in ICM=1 (compensation mode), not clear in ICM=0. (standard)

(Note) After Learning memory clear, this bit is set to 0. (cf. 7.1.2 Processing flow)

PRFCLR In case of ICM=1 (Compensation mode),
1 : Learning memory specified by profile number (No.2511) is anytime cleared out.
0 : Learning memory is not cleared out.

(Note) After Learning memory clear, this bit is reset to 0. (cf. 7.1.2 Processing flow)

QUCKST Learning control is executed
1 : at High-speed cutting (G05)
0 : at High-speed cutting (G05) and not zero command

2229	TAWAMI	STPRED	HSSATU			RCNEG	TIMADJ	ABSEN

STPRED The first period subsequent to Learning step switching,

1 : Doesn't renew Learning data in Learning memory.

0 : Renew Learning data in Learning memory. (standard)

(Note) In case of Compensation mode, this function reduces a mechanical shock at switch of Learning step by suspending the renewal of Learning data only during the first period subsequent to switch of Learning step . This might have good result on such grinding application that have many and rapid Learning step switch.

2516	RPTCT	1st Learning count (Repetition count) [cycle]

Data range : 0 to 32767

Standard : 32767

After Learning data is renewed up to RPTCT, the renewal is stopped.

You can temporally disable Learning control by setting RPTCT to zero before G05.

2517	PRIOD	1st Learning period (Command period) [msec]

Data range : 15 to 32000

You should set Command data period PRIOD corresponding to spindle rotary speed usually. Servo software regards this as Learning period. You can set integer times of the command period to PRIOD. Max. value is 32sec and correspond to 1.875 min^{-1} of Min. spindle rotary speed.

(Example) When spindle speed is 60min-1, set to 1000 (msec) in case of No.2442#3 = 0.

2518	RPTCT2	2nd Learning count (Repetition count)	[cycle]
2519	PRIOD2	2nd Learning period (Command period)	[msec]
2520	RPTCT3	3rd Learning count (Repetition count)	[cycle]
2521	PRIOD3	3rd Learning period (Command period)	[msec]
2522	RPTCT4	4th Learning count (Repetition count)	[cycle]
2523	PRIOD4	4th Learning period (Command period)	[msec]
2524	RPTCT5	5th Learning count (Repetition count)	[cycle]
2525	PRIOD5	5th Learning period (Command period)	[msec]

If the multiple Learning period is necessary, you use 2nd Learning, 3rd Learning, and etc. This function assumes the cam grinding machine as the work is finished changing the Learning period. According to Fig.3-3-3 example, use these parameters.

2515	STPRPT	Step repetition count

When this parameter is set, Learning controller repeats the learning steps.

(Example) In case No.2232 = 2, Learning steps exist up to the 3rd Learning step.

$$\underbrace{1^{st} \rightarrow 2^{nd} \rightarrow 3^{rd}}_{0} \rightarrow \underbrace{1^{st} \rightarrow 2^{nd} \rightarrow 3^{rd}}_{1} \rightarrow \underbrace{1^{st} \rightarrow 2^{nd} \rightarrow 3^{rd}}_{2}$$

2510	PRFALL	Total profile number

Data range : 0 to 16

Standard : 0

With regard to Total profile number details, refer to **7.1 Learning memory expanded function**.

2511	PRFNO	Profile number

Data range : 0 to PRFALL (Total profile number)

Standard : 0

Learning result is memorized by each profile.

2514	LESTTM	Learning start time [msec]

Data range : 0 to 16000 (When No.2007#3 = 1, to 32000 [Velocity sampling time])

Standard : 0

Learning control starts usually from non-zero command after the High-speed cutting (G05) starts. If this parameter is set to LESTTM, Learning control starts at LESTTM [msec] late from non-zero command appeared. Regarding use example, see Fig.3-3-3.

2513	BRCT	Learning suspension count [cycle]

Data range : 0 to 32767

Standard : 60 (When Position gain is $30s^{-1}$)

10 (When Position gain is $180s^{-1}$)

In case of Suspension mode or Compensation data suspension mode, set the suspension times of Learning data to BRCT with Learning period being one until you want to stop the renewal. You have to determine BRCT to reduce the position error to minimize by Learning control.

Position gain affected BRCT value. If position gain is smaller, the more BRCT is required. So make sure of actual BRCT by the practical machine.

2542	SHKRDC	Shock reducing counter [msec]

Data range : 10 to 20 (Velocity 1msec)

1 to 5 (Velocity 0.5msec)

(Note) This parameter must be below Command period (No.2517 etc).

Standard : 0

This parameter is useful for reducing the mechanical shock at finishing Learning control.

The Learning controller halts to output Learning data for SHKRDC [msec] from the end during the final

cycle.
Servo software judges the final cycle by the Learning count (No.2516, No.2518, or etc).

2512	FBND Frequency band of low pass filter [Hz]

Data range : 0 to 700 stepping up every 50 (When Velocity 0.5msec)
0 to 350 stepping up every 25 (When Velocity 1msec)
Standard : Refer to **Appendix 3. Parameter table for Learning control**.

FBND decides the band-width of Learning controller, so the higher is the better as far as being stable. The maximum value in the range where there is no vibration is set. Be careful, if the command by user includes the high frequency spectrum exceeds FBND, the error of the frequency spectrum does not converge.

(Note) If you set 0, Learning control isn't performed. You can disable Learning control without power off.

2526	GODMX Maximum order of Gx

Data range : 0 to 20
Standard : Refer to **Appendix 3. Parameter table for Learning control**.

2527	GODMN Minimum order of Gx

Data range : 0 to GODMX
Standard : Refer to **Appendix 3. Parameter table for Learning control**.

(Note) In case of Expanded Gx being enable (No.2443#3 = 1), set GXDMN to 0.

2528	GCOEF / EXGXK1 Coefficient of Gx / Coefficient 1 of expanded Gx

Data range : 0 to 128
Standard : 64 (When No.2443#3 = 0)

(Note) In case of Expanded Gx being enable (No.2443#3 = 1), Refer to
Appendix 3. Parameter table for Learning control.

In case of Expanded Gx chosen with EXGX (No.2443#3) one set, you need to set for the following parameters.

2529	EXGXK2	Coefficient 2 of expanded Gx
2530	EXGXK 3	Coefficient 3 of expanded Gx
2531	EXGXK 4	Coefficient 4 of expanded Gx
2532	EXGXK 5	Coefficient 5 of expanded Gx
2533	EXGXK 6	Coefficient 6 of expanded Gx

Standard : 0

Note

1) Dynamic characteristic compensation Gx is composed from three parameters No.2526, No.2527, No.2528, which symbols are GODMX, GODMN, GCOEF respectively. Furthermore six successive parameters from No.2528 to No.2533 are named Expanded Gx.
2) Attention to No.2528 double assigned by both Gx and Expanded Gx. Either of Gx or Expanded Gx is to be active, not both.
3) In usual case you need not to change Gx or Expanded Gx from **Appendix 3. Parameter table for Learning control** so long as the problem of the accuracy doesn't occur.
4) If it occurs, you need to tune three parameters of Gx after reset EXGX (No.2443#3) to zero. Due to many parameters of Expanded Gx, it is recommended to disable it by EXGX=0.
5) Gx compensates the characteristic of controlled object. GODMX and GODMN improve the phase characteristics of controlled object. The greater both values are, the more advance value of phase it have. GCOEF is the compensation parameter to improve the gain characteristics of controlled object. As the values are greater, the value of gain gets greater. There is a predetermined parameter set fit to each properties of the motor such as velocity gain and position gain.
6) If there is not a parameter set you want to use, please consult to our sales.

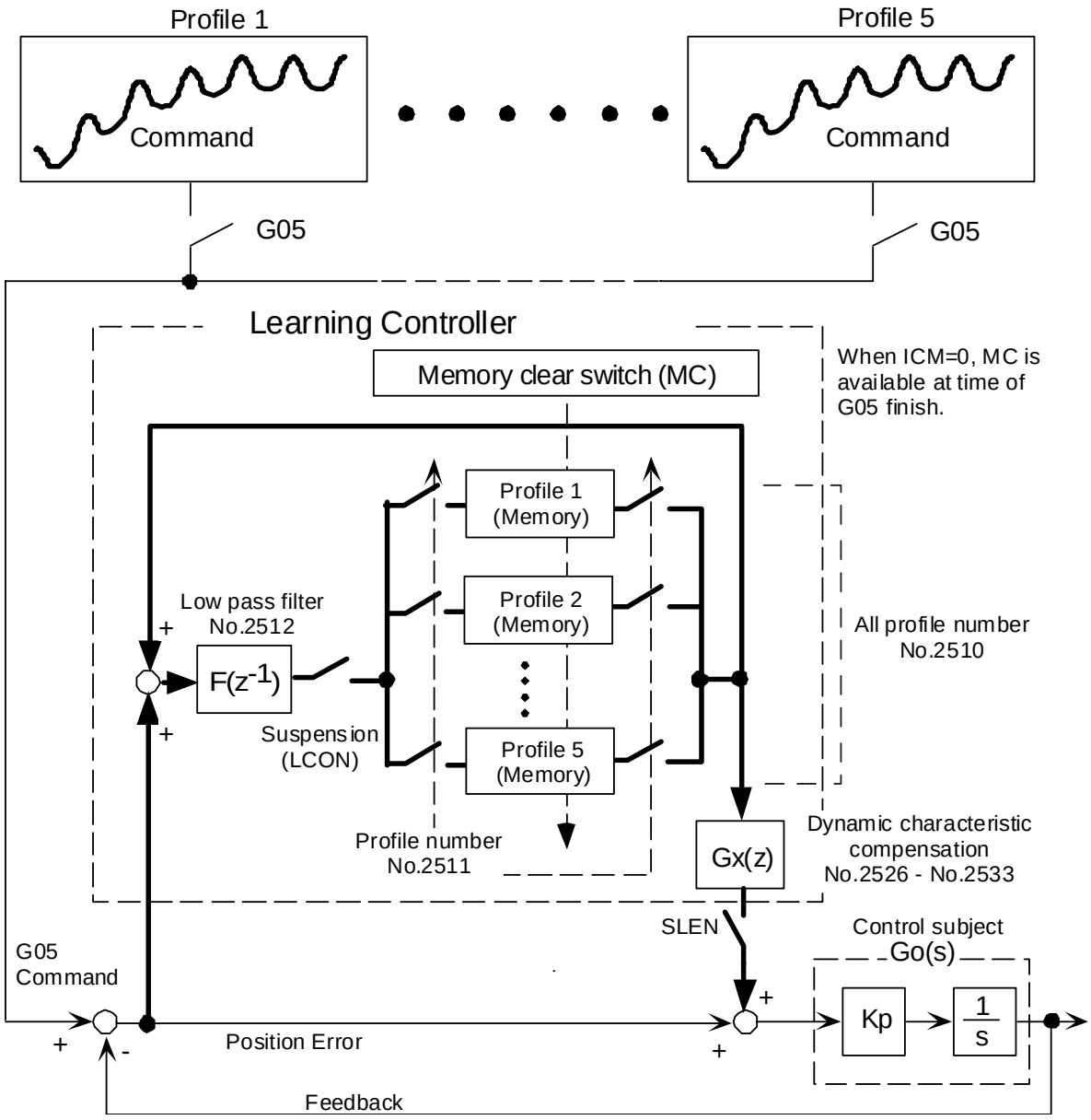


Fig.6-1 (1) Learning control block diagram

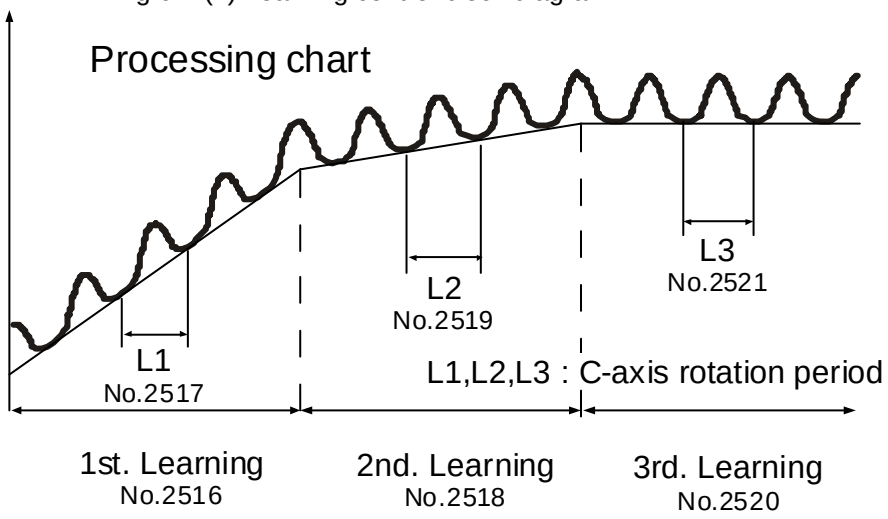


Fig.6-1 (2) Processing chart (Learning Step)

				Title	90D3 / 90E3 Learning Control Operator's Manual
				Draw No.	A - 63639E - 108
01	'05.04.20	N.Sonoda	Newly designed	FANUC LTD	Sheet 032 / 064
Edit	Date	Design	Description		

6.2 **Adaptive Preview Control Parameters**

2019	DPFBCT	SLEN	INVSYS	SUPRSY	LBUFEX		TRANDE	

INVSYS Adaptive Preview Control (Option) is
1 : Available. ♦ CNC software option is necessary
0 : Not available.

2442			ADERSL	VCMDCL	UNTSL	TRASMT	ADAPT	

ADAPT Feed-forward coefficient FORW1-6 is
1 : Adapted by using ADPCE (During adaptation, Learning control is invalid automatically)
0 : Not changed

TRASMT Set this to zero usually. After FORW1-6 is decided by adaptation, set this to one in order to transmit them to No.2544-49, then turn it back to zero.
1 : Transmit FORW1-6 automatically to No.2544-49 with adaptive mode each time at G05 end.
0 : Not transmit FORW1-6.

ADRERSL Adaptive control uses
1 : the velocity error.
0 : the position error. (Standard)
(Note) Usually this is applied to rotary axis, which the command changes.

2543	ADPCE Adaptation coefficient

Data range : 0 to 1000
Standard : 50
This parameter gives an influence of the adaptation speed and final error. Set to the biggest value so far as the error is not diverge.

2544 - 2549	FORW1 – FORW6 Feed forward coefficients W1 - W6

Data range : -32768 to 32767
Standard : 0
Feed forward coefficients *FORWi* are usually decided by Adaptive mode. Also you can calculate by the following expression.

$$FORWi = \frac{fi}{100} \times 2^{16} \times \frac{\text{PULCO}}{\text{PPLS}} \times \frac{\text{SMDR2}}{\text{SMDR1}} \times \frac{1}{80}$$
$$= \frac{fi}{100} \times 2^{16} \times \frac{\text{PULCO}}{\text{L}}$$

fi is feed-forward coefficient (%). And PULCO is No.2023, PPLS is No.2024, SMDR1 is No.2084, SDMR2 is No.2085. *L* is movable distance (detection unit) per one rotation of motor. Above formula is for semi-closed system or separated serial rotary encoder system. Below formula is generalization. The more the summation of all coefficients is near 100%, the more it is better result.

Ex.1. In case of semi-closed system with 200,000 pulses per motor revolution,
The parameters are set to PULCO=8192, PPLS=12500, N2084=20, N2085=100.

FORWi = 100% / 100 $\times$ 2^{16} $\times$ 8192 / 200000 = 2684

The summation of all coefficients must adapt to near 2684 after adaptive mode.

Ex.2. In case of full-closed system with 1/32 reduction and 3600,000 pulses per C-axis revolution,
The motor revolution is 3600000 / 32 = 112500.

FORWi = 100% / 100 $\times$ 2^{16} * 8192 / 12500 = 4772

If the adaptive mode doesn't work well due to constant speed, set each coefficient to 4772/6=795. And you are able to get the same effect as feed forward 100%.

Ex 3. In case of changing from SDMR1 = 10, SDMR2 = 100 to SDMR1 = 5, SDMR2 = 100,

FORWi (new) = *FORWi* (old) $\times$ 10 / 100 $\times$ 100 / 5
= *FORWi* (old) $\times$ 2

6.3 **Adaptive method**

The feed-forward coefficients of the Adaptive preview control are decided with the following procedure.

A-1 Validate the Adaptive preview control and the Adaptive mode.
(No.2019#5 = 1 and No.2442#1 =1)

A-2 Set the parameter of the adaptation coefficient to standard setting.
(No.2543 =100)
Set the feed-forward coefficients to all 0. (No.2544 - 2549 = all 0)
And Learning control is invalid automatically during adaptation.

> Caution
> As soon as the error begins divergence, stop G05 by reset key on MDI to protect the machine from excessive shock.

A-3 Operate the machine about several ten times of the learning cycle with a practical part program including G05.

A-4 Check the position error with Servo guide or the servo tuning display.

A-5 Step up adaptation coefficient (No.2543) every about 50.
Check Convergence of the position error by using the possible biggest coefficient as far as the error diverges.

A-6 Invalidate the adaptive mode. (No.2442#1 = 0)
The feed-forward coefficients decided by the adaptive mode are not transported from servo to CNC on this phase.

A-7 To transmit the feed-forward coefficients to NC nonvolatile memory No.2544-49, set No.2442#2 = 1.

A-8 If the feed-forward coefficients change from initial value to another one, the transportation to CNC parameter has finished.

A-9 Set No.2442#2 = 0.
Finish with adaptive process.

These processes can decide the feed-forward coefficients. Make sure No.2443#1 and #2 to be 0.

7. Functions detail

7.1 Learning Memory expanded function

Learning Memory expanded function allows the application to take advantage of many profiles up to Max. Profile number and many learning steps up to Max. Learning step number as the following table. (Option)

	Max. Profile number	Max. Learning Step number
Standard spec.	5	2
Expanded spec.	24	5

7.1.1 Parameter explanation

2019						LEBFEX			

LEBFEX Learning Memory expanded function is

1 : Available (New spec.)

0 : Not available (Old spec.)

(Note) Learning Memory expanded function also requires NC option besides.

2510	PRFALL Total Profile number

Data range : 1 to 16 (New spec.) Old spec is 0.

♦ In case of Cam grinding, total profile number for one camshaft is set before processing.

2511	PRFNO Profile number

Data range : 1 to PRFALL (New spec.) Old spec. is 0 to 5.

♦ Set the Profile number at the entry of G05 cutting the next profile, if you want to change the profile.

♦ When PRFNO = 0, you can't use the second and after Learning period and repeat number. Only PRIOD and RPTCT of the first Learning parameter are available.

When the following parameter No.2537 isn't equal to zero, Learning period is expressed as the product of No.2537 and No.2517. In this case, Learning steps from second step are unavailable.

2537	EXPRIOD Expansion coefficient of Learning period

Data range : 0 to 32767 (If 0, it regards as 1)

2517	PRIOD 1st Learning period (msec)

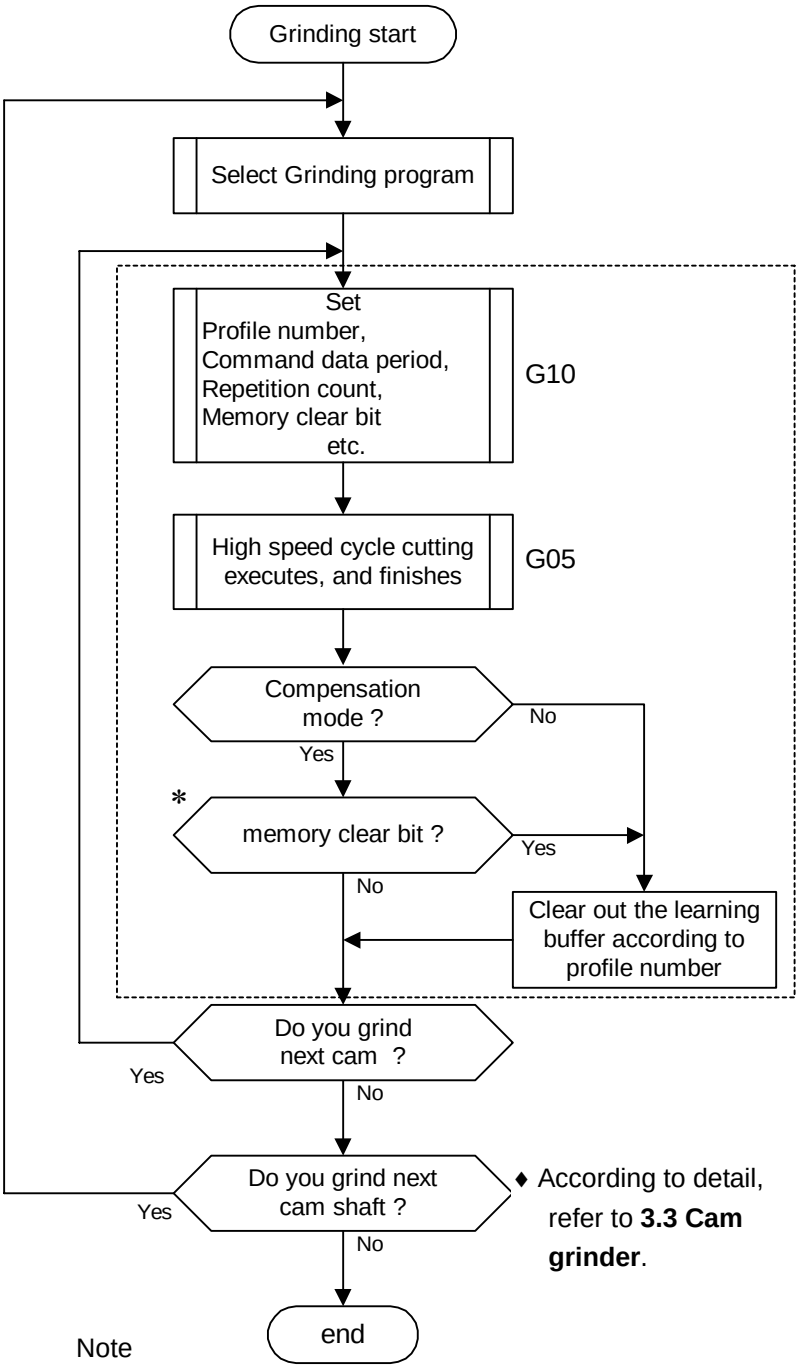
Example : If you want to set whole process 64sec as Learning period, the setting is as follows.

No.2517 = 6,400, No.2537 =10

Actual Learning period = 6,400 * 10 = 64,000msec

Note : These parameters enable to set over 32sec as Learning period. But according to the formula from "7.1.3 Cautions", there is some possibility that the accuracy getting worse because of rough sampling. In this case, it is necessary to reduce the total profile number.

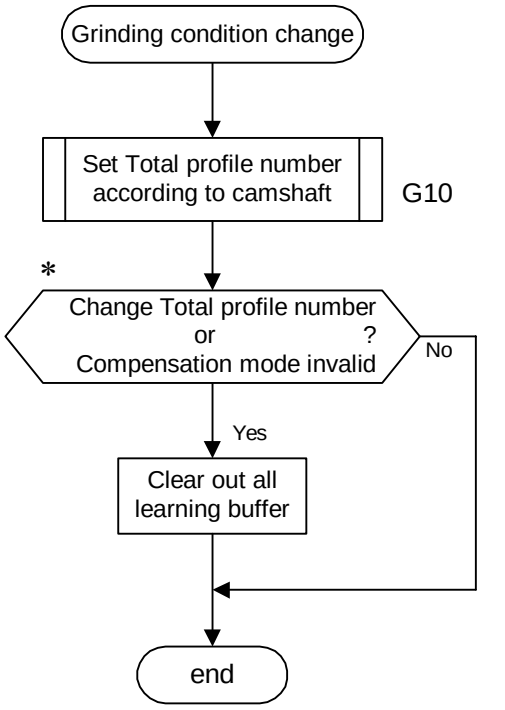
7.1.2 Processing flow



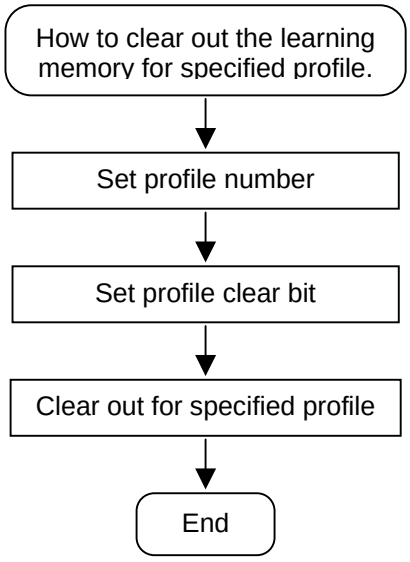
♦ According to detail, refer to **3.3 Cam grinder**.

Note

Set 0 for the Repetition count and Command data period of Learning steps you don't use.



♦ When Total profile number is changed or Compensation data mode is invalid, all learning memory is cleared.


How to clear out the learning memory for specified profile.
Set profile number
Set profile clear bit
Clear out for specified profile
End

♦ After clear, profile clear bit (No.2226#6) is reset automatically. Don't set profile clear bit in G10.

How much time is necessary to clear all Learning memory?

- 90D3 ------ 2.3 seconds (Regardless of HRV3, HRV4)
- 90B3, 90B7 ------ 2.0 seconds

Clear time is 9.0 sec. at HRV3, 18.0 sec. at HRV4.
If G05 is executed before finishing memory clear, illegal servo parameter setting alarm occurs. In order to avoid the alarm, please confirm the following signal before starting G05.
F322 : getting 1 during memory clear

7.1.3 Cautions

Learning memory-expanded function realizes the expansion of learning memory by altering a sample rate. It has automatically the sampler gather the data roughly every 2 to Nth power in case of long Learning period or many profiles and Learning steps, because of which case many compensation data run out of the memory belong to servo DSP. There is the possibility for rough sampling to make the accuracy inferior to one without Thinning out.

- **Calculation method of the sampling period in case of Total profile number PRFALL ≠ 0**

  Definition: BUFSIZE is the buffer-size of which possible capacity depends on the installed memory on PCB controlling axis. BUFSIZE is following.

Servo Software	PCB order spec.	BUFSIZE (sample data)
90D3	A02B-0303-H088	290816
90B3, 90B7	A02B-0236-H088	76800

Maximum Learning period : **Max_PRIOD** is Learning period PRIOD that have largest period among from 1'st to 5'th Learning steps.

Total profile number: **PRFALL** is No.2512

Learning step number in use: **STEPNO** is the number you are using as Learning step setting from No.2518 to No.2525.

$$\frac{\textbf{Max\_PRIOD} \times \textbf{STEPNO}}{\textbf{BUFSIZE} / \textbf{PRFALL}} \leq 2^n = MULT \qquad (n = 0, 1, 2, ...)$$

Exponent of 2: **n** is calculated by above formula and the sampling period is the multiple of 2 to n'th power.

Learning period automatically samples every above MULT and the parameter PRIOD should be set to the multiple of MULT.

[Example] Supposing you use 24 profiles in one camshaft, which means PRFALL=24. A profile of them is ground using 5 Learning steps, among which the longest Learning period is 6000 msec. That is Max_PRIOD=6000 (msec), STEPNO=5, BUFSIZE=290816.

Above formula result in n=2 meaning MULT=4. Therefore sampling period gets fourth time.

Note

Because of Max_PRIOD of a profile deciding one MULT, another step of the profile have the same sampling rate as result. This mean, though one profile has the common sampling rate all over, there is possibility the different sampling rate may be used on different profile.

Exceptionally in case of PRFALL=0, calculate above with it to five.

7.2 Learning Data Transmission Function

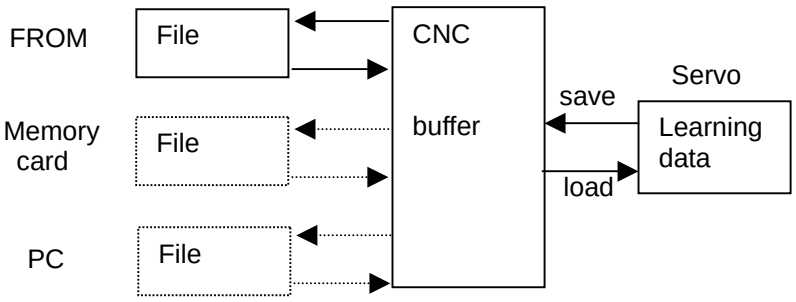
7.2.1 Overview

For the purpose of preserving Learning data after NC powered off, Learning data can be preserved in nonvolatile flash ROM, which store Learning data through CNC and load it the memory of servo control. (Learning data transmission function)

This function will be effective not only for the power off but also for saving the learning time in case of handling many profile of work piece.

This allows user to manage the command data (parts program) and Learning data corresponding to flash ROM.

This function allows you not to need to learn again every NC power off.



7.2.2 Necessary Software construction

1) Servo software
   series 90D3 01 or later
2) CNC software
   Series 30*i*-A, A02B-0303-H501#G002/ G012/ G022 –version 10 or later
   Series 31*i*-A, A02B-0307-H501#G101/ G111 –version 10 or later
   Series 31*i*-A5, A02B-0306-H501#G121/ G131 –version 10 or later

The equal or over version of above CNC software is available for this function.

3) Application program by user on PC
   Application program made by user practically saves and loads the learning data between HD of PC and the servo memory. The software library is supplied by FANUC for this purpose.
   You can read and write the learning data using this library.
4) Transmission time
   Usually transmission time is 128 words data per 4 msec. Therefore 524k words data transmission takes about 18.4 sec. Furthermore it is possible to transfer learning data until 4-axes at the same time.

7.2.3 Servo parameter

In order to transmit (save and load), the below setting is necessary.

No.2019#6=1 : Enable Learning Control
No.2443#6=1 : Enable Compensation data mode

You must take care the following parameters when you save and load the Learning Data.

No.2019#3=1 : Learning memory expanded function (Option)
No.2511 : PRFNO: Profile number
No.2510 : PRFALL: Total Profile number

7.2.4 How to transmit Learning Data

- **To SAVE Learning Data (Servo → HD)**

1) All of the first, you must confirm the error of Learning control converged well.

2) Set No.2511 of Profile number to zero in case of the *lump deal method*.
Check No.2510 of Total Profile number beforehand.
Note) You can SAVE Learning Data every the profile data, which is called the partial deal method.
(The transmitted area of Learning Data is the shade of Fig.7.1.)
The ***lump deal method***: No.2511=0 ;Saving all Learning data of an axis.
The ***partial deal method*** : No.2511= Profile number ;Saving the specified Learning Data.

3) Set CNC to EDIT mode and then you can transmit it to HD on PC using your application software. Blinking "RESET" denotes busy state on transmit.

Note
1) You can't change parameter or run with parts program simultaneously with this function.
2) The format of Learning Data is not disclosed which is the binary data. Don't edit it, otherwise there might be possibility not to transmit well.
3) It takes about 18 seconds for transmission from Servo to CNC in case of the lump deal method.

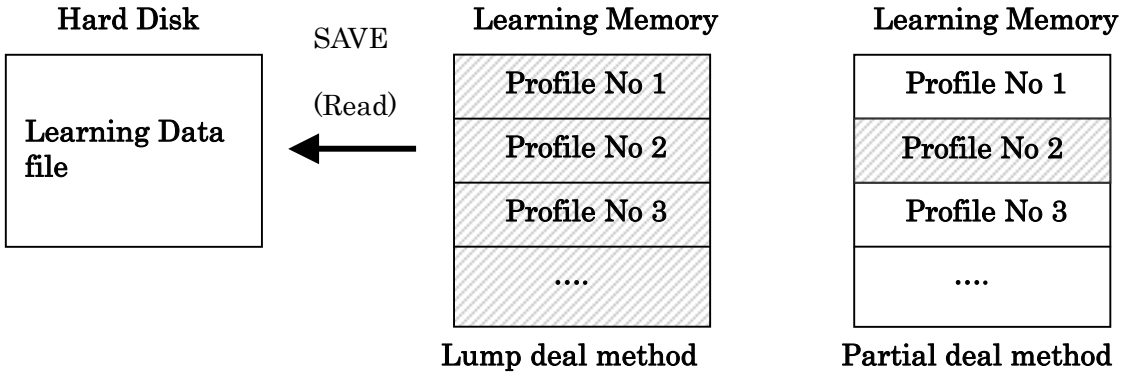


Fig 7.1 To SAVE Learning Data by two ways of
the Lump deal method (No.2510=0) and the Partial deal method (No2510=2)

- **To LOAD Learning Data (HD → Servo)**

1) Set No.2511 of the Profile number to zero in case of the lump deal method.
Learning Data saved by the lump deal method must be loaded by the lump deal method.
Check No.2510 of the total number of Profile to be same value as saved before. (It must be so!)
- Set No.2511 =0 when the Learning Data was saved by the lump deal method before.
- Set No.2511=Profile number when it was saved by the partial deal method.

Note) You can load Learning Data to the number different from it when saved before in just case of the partial deal method.

2) Set CNC to EDIT mode and transmit Learning Data from HD to servo memory through your application software. Blinking RESET indicates on transmission.
Note) When loading, No.2510 of total profile number is checked automatically whether it is the same or not as it was saved beforehand. If they are not identical, the transmission alarm occurs

3) Set No.2511 to an appropriate value and then start to run Learning function.

Caution

It is necessary for you to manage the Learning Data together with its parts program (:command). It would be dangerous because of the unexpected movement if you ran the parts program different from correspondent Learning Data. Furthermore you must be conscious of the profile number No.2511 which have Learning data that should be handle always together with the command data.

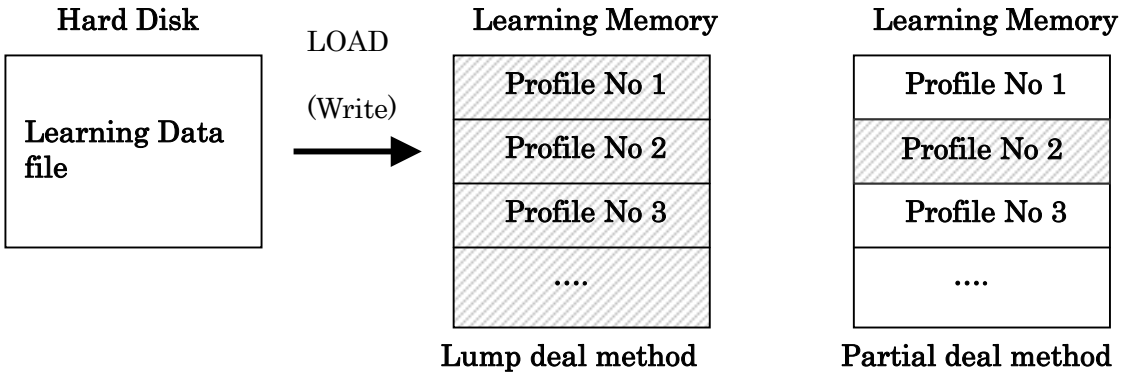
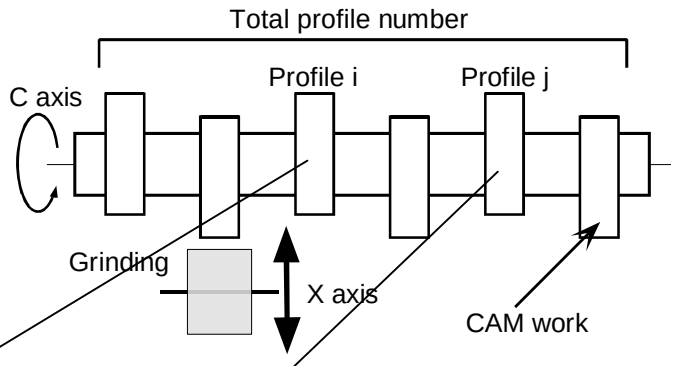


Fig 7.2 To load Learning Data by two ways of
the Lump deal method (No.2511=0) and the Partial deal method (No2511=2)

7.2.5 Examples

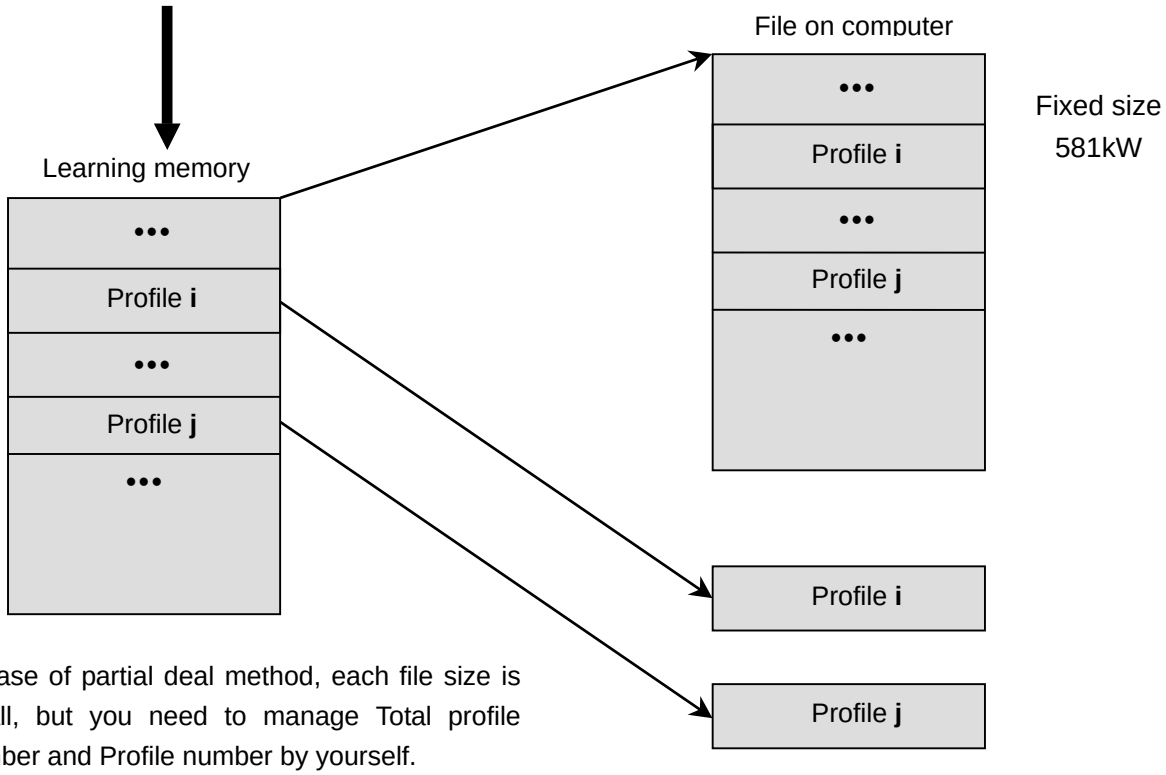
(1) Correspondence with processing program and Work

```
O0001 ;
G10   L50 ;
N2510   P (Axis)   R (Total profile number) ;
G11 ;
        ••••••
G10   L50 ;
N2511   P (Axis)   R (Profile number i) ;
N2516   P (Axis)   R (Learning count) ;
N2517   P (Axis)   R (Learning period) ;
        •• (each step) ••
G11 ;
G05 (Profile i command) ;
        ••••••
G10   L50 ;
N2511   P (Axis)   R (Profile number j) ;
N2516   P (Axis)   R (Learning count) ;
N2517   P (Axis)   R (Learning period) ;
        •• (each step) ••
G11 ;
G05 (Profile j command) ;
        ••••••
```



Above case consists of six profiles in one camshaft, supposing all have different profile each other.

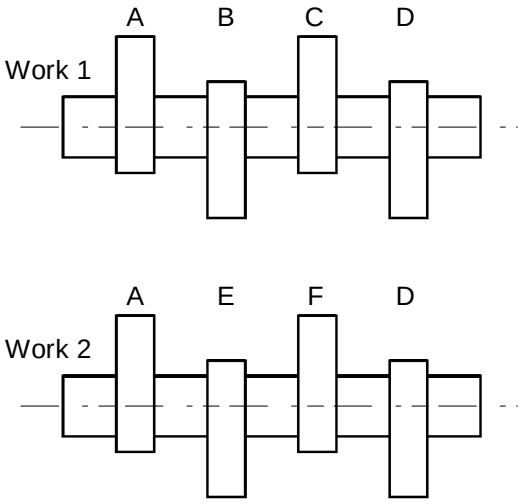
(Max. 24 profiles are available)



In case of partial deal method, each file size is small, but you need to manage Total profile number and Profile number by yourself.

(2) Example of file management by Partial deal method

We describe the case that Work 1 and Work 2 on right figure is processed in that order. This case supposes PC has already Learning data in the HD of A,B,C,D,E,F.



1) At first you should fix Total profile number PRFALL to 4 .
2) According to the process of Work 1, you should load Learning data of Profile A, B, C, and D to corresponded servo memory area (Profile number 1, 2, 3, and 4).
3) You should process Work 1 making each command correspond to Profile number.
4) When the next process of Work 2, you should load the Learning data of Profile A, E, F, and D to corresponded servo memory area. But you have only to load Profile E and F to corresponded servo memory area (Profile number 2 and 3) because Profile A and D already exist.
5) You should process Work 2 making each command correspond to Profile number.

You must always manage the correspondence between a Profile data (a G05 command) and the Learning data. Furthermore you must manage the correspondence between Work and Profile number (Total profile number).

7.3 Torsion compensation during High-speed cycle cutting function

This function adds the compensation at the point of the command reversing sign during High-speed cycle cutting (G05), This function is useful for the case that the reverse point of work piece has sharp drop because it is easy to bend for the weakness.

This function works only during G05, different from normal backlash compensation function. And this function forces the sum of compensation always to be zero during G05. Therefore this function can be used in case that the compensation value is changed every work piece, which is useful properties for the machining.

7.3.1 Parameters

2229	TAWAMI							

TAWAMI Torsion compensation during G05

1 : useful.

0 : is not useful. (Standard)

2544	Torsion compensation during G05 (Least detective unit)

When Motion command (Mcmd) changes from the plus to the minus, the minus value is added.
When Motion command (Mcmd) changes from the minus to the plus, the plus value is added.
(This method is like to the backlash compensation.)

- Restrict
  Odd axis in N1023 (only L-axis)
  Only during High speed cycle cutting (G05)

- Feature
  Torsion compensation value is added to Error counter when the sign of latest Mcmd reverses against the sign of the former Mcmd except Mcmd = 0.

7.4 Tandem Learning control function

7.4.1 Summary

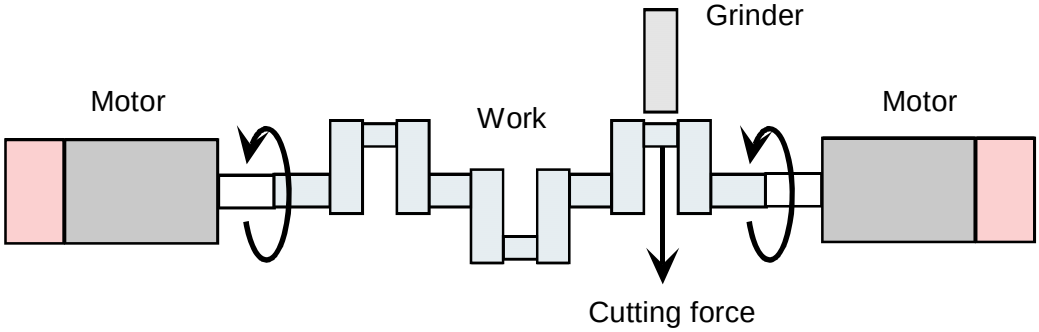
Tandem Learning control is Learning control combined with Tandem control. By means that two motors are controlled as one axis and Learning control is added, this function can achieve high precision processing in the special applications.

Note	This function is available with series 90D3 version 02 or later.

1) Position Tandem Learning control

Merit : It can realize high accuracy to learn the position deviation with both sides of long workpiece which have weak stiffness chucked and driven by two motors.

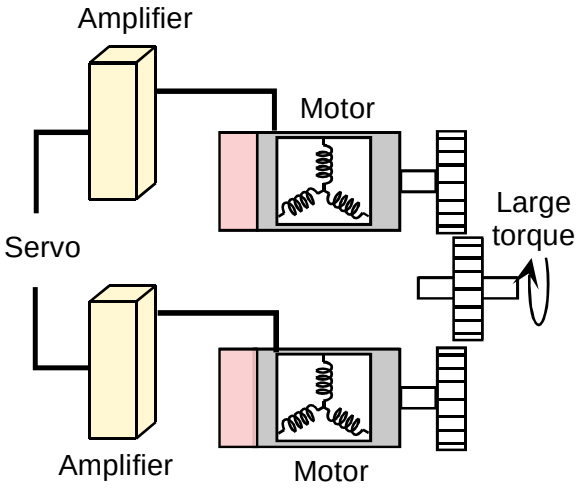
Applicable machine : Cam grinder, Crankshaft grinder, and etc.

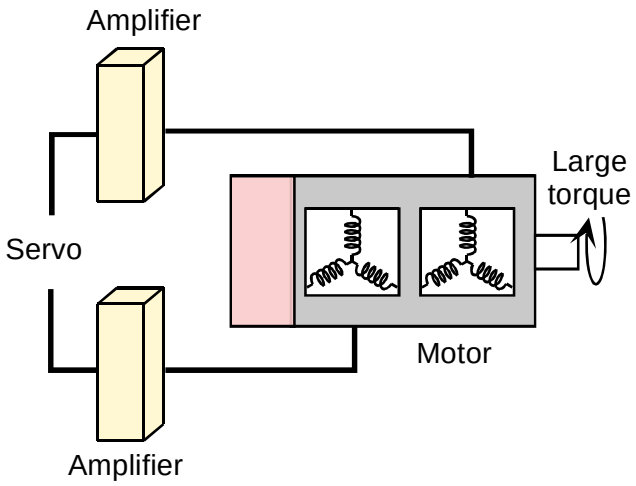


2) Torque tandem Learning control

Merit : Large torque of double motor can achieve leaning of the position deviation due to large cutting torque. αis300 or αis500 requires torque tandem in spite of single motor, because they have double coils inside one motor and use two amplifiers. We call this "***double coil tandem*** control" as a special case of torque tandem.

Applicable machine : Helical gear shaper without helical slide, Helical broach machine, Accurate press, etc





7.4.2 Parameters

1817		TANDEM						

TANDEM Tandem control (Power must be off) (NC Option)

0 : Available.

1 : Not available

In case of Torque Tandem Learning control that main and sub motors don't disconnect mechanically, set this bit to 1. But in case of the application that both motors disconnect by the operator such as double side chucking, set this bit to 0. Of course the double coils tandem requires TANDEM to be one due to the former case.

1023	Servo axis allocation

You should set Main axis to the odd (L-axis), Sub axis to the subsequent the even (M-axis).

2007						SUBDEP		

SUBDEP Sub axis separation function (Set **only main axis**)

0 : Ignore coupling flag (external user signal through PMC).

1 : On/OFF of Tandem disturbance elimination control and Velocity feedback average function switched by coupling flag. (TANDEM Learning bit must be zero)

2008	LAXDMP					VFBAVE	(TNDM)	

LAXDMP Dumping compensation function is applied to

0 : sub-axis only

1 : both main and sub-axis (normal setting)

VFBAVE Velocity feedback average function is

0 : invalid

1 : valid (normal setting)

(TNDM)

0 : Not on Tandem control

1 : On Tandem control (This bit synchronizes with No.1817#6.)

2018	PFBCPY							

PFBCPY Common motor feedback function (Set **only Sub axis**)

0 : Sub axis uses the sub axis feedback.

1 : Sub axis uses the main axis feedback.

In Torque Tandem Learning control for αis300 or αis500, you should set PFBCPY to one for double coil tandem control. In case of the sub axis having the feedback, set PFBCPY to zero.

2228								
								SYSLRN

SYNLRN Synchronous Learning function (Set **only Main axis**)

0 : Ignore coupling flag, which is external user signal through PMC

1 : Learning control for both Main and Sub axes executes by coupling flag.

This bit is used in Position Tandem control. Synchronous Learning function works with Main and Sub axes connected by work piece driven by the same Learning compensation data.

2087	Preload torque

(Note) Set for both Main and Sub axes.
Set zero in case of double coil tandem or the position tandem learning control.

2036	Damping compensation Gain Kc

(Note) **Set only to Main axis**.

2036	Damping compensation phase coefficient α

(Note) **Set only to Sub axis**. **Set zero** usually

Regarding Preload and Damping compensation, and how to tune the Tandem, refer to **4.16 Tandem control function** in "FANUC AC SERVO MOTOR αi series Parameter manual" (B-65270E).

7.4.3 External signal interface

Supposing Main and Sub motors are ready to chuck the each edge of one work piece. Before chucking both motor can be driven independently. When both motor connected by workpiece for the cutting, you send Coupling flag to servo software through PMC in advance to enable "Sub axis separate function", then G05 operation start Torque tandem Learning control. After cutting of G05 finished, Coupling flag allows the independent drive of both motors. If you want Position tandem Learning control instead of Torque tandem, use "Synchronous Learning function" instead of "Sub axis separate function".

Signal address

G321	SVDI28	SVDI27	SVDI26	SVDI25	SVDI24	SVDI23	SVDI22	SVDI21

The position of above bit means the axis of NC. For example, bit 0 is first axis of NC.
0 : coupling, 1 : non-coupling

7.4.4 Mode table

TANDEM (N1817#6)	SBDYCH (N2007#2) main	SYSLRN (N2228#0) main	SYNx (G321)	Mode	Remark
0	0	0	X	Independence	normal
1	0	0	X	Tandem	Fixed, N2018#7=1
0	X	1	1	Independence	Main-axis learning / Tandem disturbance elimination filter OFF
			0	Synchronism	Synchronous Learning / Tandem disturbance elimination filter ON

Note

When Synchronous Learning function is available, Tandem disturbance elimination control and Velocity feedback average function are switched by Coupling flag regardless of Sub axis separation function.

7.5 Error monitoring function

Error monitoring function is useful for watching accuracy of work during processing and for judging convergence of position error.

2550	LERRLV	Error monitoring level (detective unit)

Data range : 0 to 32767

(Note) If this value is 0, position error monitoring function is not available.

2551	ERMOST	Error monitoring start time (msec)

Data range : 0 to 32767

Standard : 0

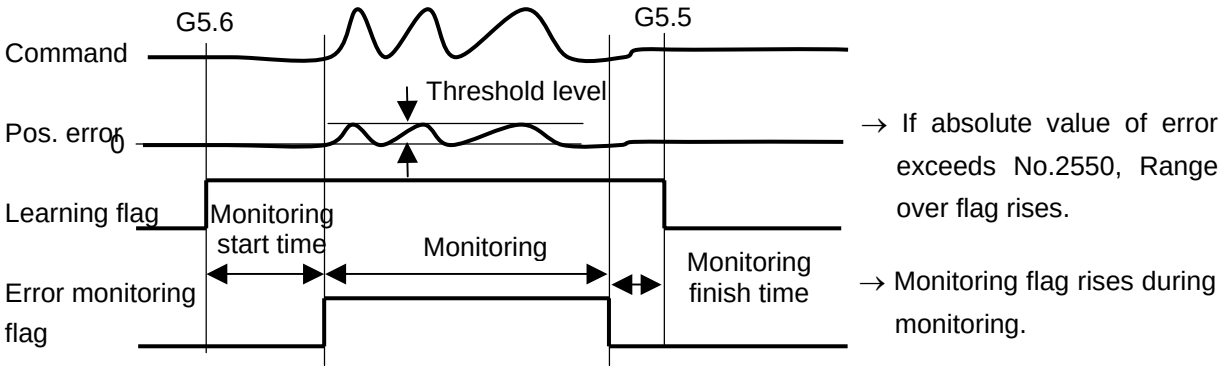
2552	ERMOFN	Error monitoring finish time (msec)

Data range : 0 to 32767

Standard : 0

This “position error monitoring function” is effective in case that you judge convergence of position error at creating Learning data or in case that you judge easily work precision at mass production

“Position error monitoring function“ is the following.



Note

1) If even position error once exceeds the threshold level during monitoring flag is 1, “range over flag” does a latch to 1. Servo software does not clear this flag until next Learning flag becomes from 0 to 1.

2) “Range over flag” is output to outer signal F321. The bit position of F321 means NC axis number.

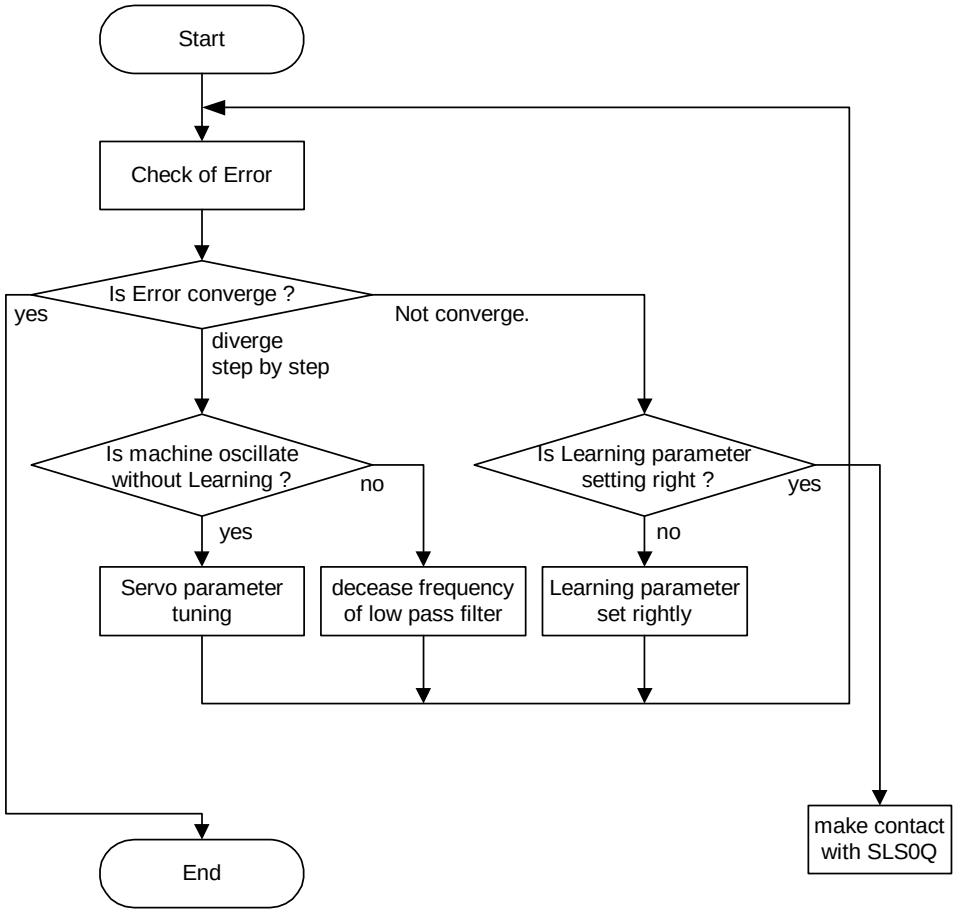
3) You should tune both “monitoring start time” and “monitoring finish time” within the range that is not influence in cutting precision to avoid becoming range over in case of excess reply in the movement beginning or stop.

8. Tuning

Regarding Learning control, you don't need to tune parameters basically.

But servo system needs to be stable before the application of Learning control. If oscillation occurs, you need to make stable by tuning Load inertia ratio (No.2021), Acceleration feedback (No.2066), Tcmd filter (No.2067), Observer function (No.2003#2), and etc.

8.1 Tuning method



Gx tuning
1) Seek the least error by added No.2526 to +1 or –1.
2) Seek the least error by added No.2527 to +1 or –1.

9. Attentions

9-1. ITP Delay Alarm

In case that CNC operation is delayed during G05 (High-speed cycle cutting or High-speed DNC operation), work piece is not processed normally. For this reason, High-speed axis checks this delay (ITP delay) during G05.

You can confirm whether this delay happened by bit 1 of ALARM4 in servo tuning screen. If CNC operation has been delayed once, this bit is 1. This bit is not cleared until power off.

On the other hand, when No.7501#7 = 1, CNC is monitoring the following cases, and displays PS alarm (N179) at the finish G05.

- The delay of High-speed remote buffer
- The above ITP delay alarm

9-2. Position check

You can check the integrated value of command pulses that Servo software receives from CNC, and the integrated value of position feedback pulses on DGN screen.

- DGN No.360 Integrated value of command pulses without compensation that CNC send to Servo.
- DGN No.362 Integrated value of command pulses that Servo software receives from CNC.
- DGN No.363 Integrated value of position feedback pulses.

9-3. Countermeasure for power failure

In case that power failure happens during synchronous operation such as G05, there is a possibility that work piece or cutting tool breaks because of no keeping synchronous relation. As the countermeasure of this case, you need to detect power failure and to retract to safety position by other axis independent from G05 execution, and to stop G05 operation keeping synchronous relations among axes.

By using both “Back-up module for power failure” and “Signal retract function”, you can rapidly get under shelter in keeping synchronous operation after power failure. Refer the following manual.

- ” Signal retract Specification”
- ” Control sequence of Back-up module for power failure”
- ” Connection of Back-up module for power failure”

9-4. Retract

When you need to stop the machine due to some reason, if RESET used during G05, there is a possibility to damage the work-piece or tool. For this case, the retract movement by external signal is able to stop safely the machine by the following functions.

Refer to the following manual.

- ” Retract of high-speed cycle cutting Specification” (Option)
- ” Skip of high-speed cycle cutting Specification” (Option)

9-5. Servo parameter alarm for Learning control

If you set the value out of appropriate range in parameters for learning control, the illegal parameter alarm occurs immediately after G05 was executed, and the detail number 83 is displayed on N352 in DGN. In this case, if the following parameters are set, furthermore detailed alarm information is displayed on N353 in DGN. This value has to convert decimal one to binary one and check the said bit parameter.

N2115=0

N2151=6265 (1879h)

The value of N353 in DGN

B3 : Filter frequency band of low pass filter (N2512) was out of range.

B4 : Profile number (N2511) was out of range.

B5 : Learning period (N2517,N2519,N2521,N2523,N2525) was out of range.

B6 : Total profile number (N2510) was out of range.

B7 : Learning memory clear hasn't been completed yet.

B8 : When total profile number (N2510) wasn't zero, profile number (N2511) was set to zero.

B9 : Learning period was too long.

9-6. Synchronized between Learning axes and the other axes

(1) Case of Learning control

Learning axis is controlled that error (delayed value) is zero. On the other hand, it is necessary to go ahead the delayed value for normal axis before G05 in case of synchronized operation, because delayed value occurs in normal axis.

Generally you should execute G05 after advancing steady-state error.

Example) rotary normal axis (position gain : Pg=30 s^{-1}) speed 600 min^{-1}, and Learning axis

Delayed value = 600 [min^{-1}] / 60 / 30 [s^{-1}] $\times$ 360 [deg/rev] = 120 [deg]

If feed-forward function is available, substantial position gain is raise. For example, in case that feed-forward coefficient is α [%], substantial position gain is 1/(1-α/100) times.

(2) Case of Preview repetitive control

1) Learning axis and normal servo axis

It is necessary to set Preview repetitive control at all servo axes in series 16*i* if Preview repetitive control is applied to at least one axis. But in series 30*i*, it is unnecessary to set it. Therefore you can set it to each axis independently.

2) Learning axis and Cs axis

It is necessary to consider the delay of normal axis against Adaptive preview control axis in series 16*i*. But in series 30*i*, it is unnecessary to consider it.

9-7. Difference between Standard and Learning servo software series in velocity loop proportional high-speed processing function

When 90B3 series replaces 90D3 series on series 30*i*, there is a case that you can't set the same velocity gain in state of HRV2 + No.2017#7=1. In this case, you should set Compatible bit (No.2227#2) to 1.

9-8. AMR offset for Linear motor

There is a description to tune an AMR offset in "Linear motor parameter setting" (B-65150、B-65270).

Appendix 1. Notes on the order

1-1. Servo axis Card (**i**-series)

You must specify the following Servo axis card for 90D3 series.

- 8 axes A02B-0303-H088 (A20B-3300-0450)

1-2. CPU card

CPU card for CNC is required 128MB DRAM type.

B3 (High-speed) A02B-0303-H005

1-3. Servo software series

You need to specify the following digital servo software for Learning Control.

90D3 series A02B-0303-H590#90D3 (A06B-6057-H509#90D3)

1-4. Software options

[Necessary items]

- Learning Control A02B-xxxx-J705 or
- Preview Repetitive control A02B-xxxx-J706
- High Speed cycle cutting A02B-xxxx-J832 or
- High-speed binary operation A02B-xxxx-J516
- Setting unit IS-C A02B-xxxx-J805

If High-speed binary operation is applied, Date Server or Open CNC is required.

"Handle interrupt function during High-speed cycle cutting" is included J832.

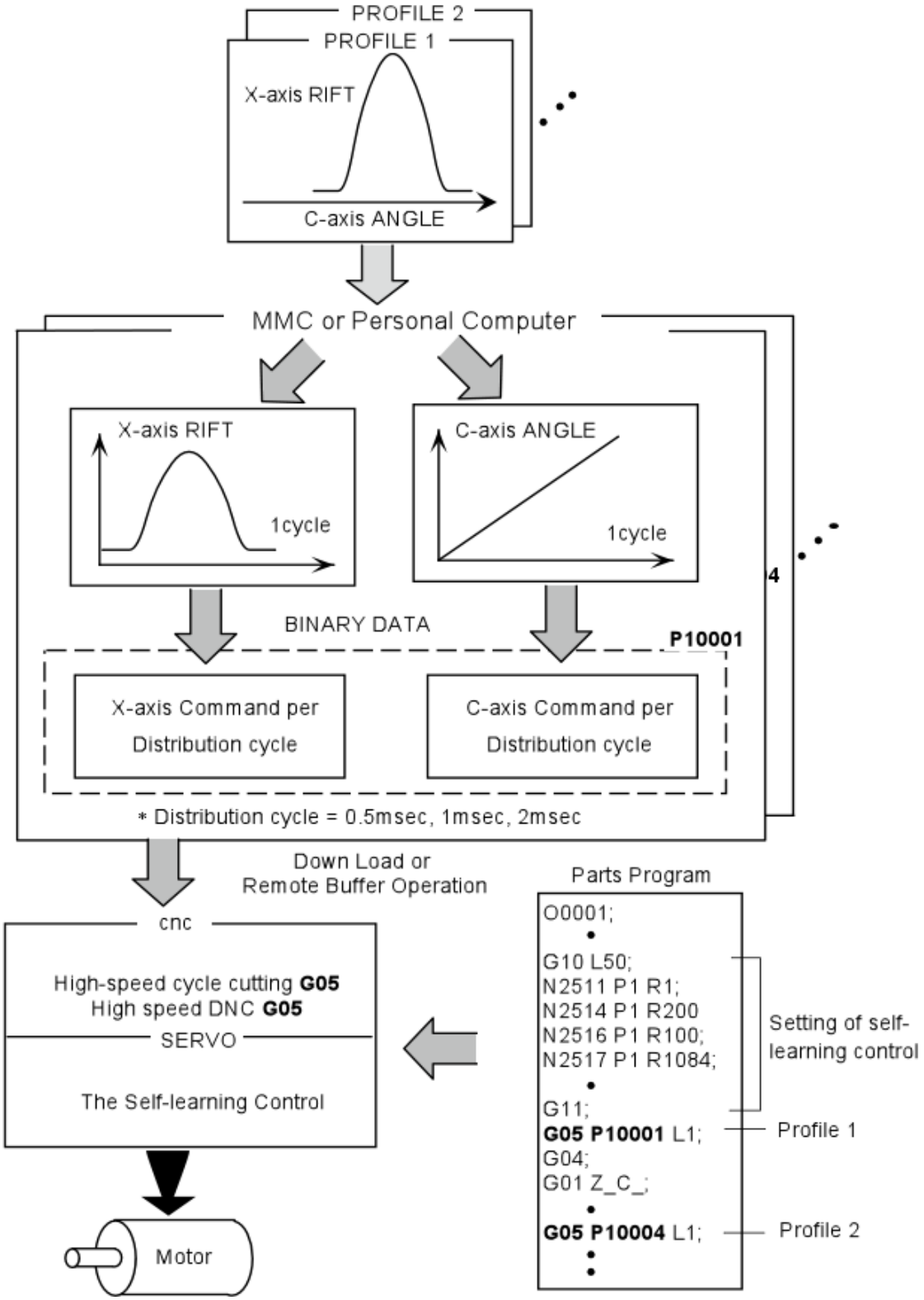
[At the need arises]

- Learning Memory expanded function A02B-xxxx-J976
- High-speed cycle cutting skip function A02B-xxxx-S662
- Retract function during High-speed cycle cutting A02B-xxxx-J663
- High cycle cutting data variable A / B A02B-xxxx-J745 / J746
- Tandem Disturbance Elimination control function A02B-xxxx-S660
- Pole Position Detection function A02B-xxxx-S744
- Macro executor A02B-xxxx-J888

♦ The above “xxxx” is the following value corresponding to each CNC.

30i-A : 0303 31i-A : 0307 31i-A5 : 0306

Appendix 2. Making method for cutting data



Appendix 3. Parameter table for Learning control

Standard Parameter for Learning Control for Piston (1/4)

	Motor type	αL9	αL9	αL9	αis8/4000	
	Motor spec.	0564	0564	0564	0235	
	Motor ID	74	74	(74)	(285)	
	Velocity	0.5ms(HS)	0.5ms(HS)	250us(HS)	0.5ms(HS)	
	Remarks	Piston	Lead Cam	Piston	Piston	
	Amplifiler	80Ap (re)	80Ap (re)	80Ap #H	80Ap	
Pg	No.1825	18000	18000	18000	18000	
PI	No.2003	00001000	00001000	00001001	00001000	
Interrupt	No.2004	11110001	11110001	11111010	00100001	
High speed	No.2005	xxx0xxxx	xxx0xxxx	xxx0xxxx	xxx0xxxx	
func. bits	No.2007	xxxxxxx0	xxxxxxx0	xxxxxxx0	xxxxxxx0	
HS Veloc.	No.2017	1xxxxxxx	1xxxxxxx	1xxxxxxx	1xxxxxxx	
Learning	**No.2019**	x1xxxxxx	x1xxxxxx	x1xxxxxx	x1xxxxxx	
HRV3	No.2013	xxxxxxx0	xxxxxxx0	xxxxxxx0	xxxxxxx0	
Compatible	No.2227	xxxxx1xx	xxxxx1xx	xxxxx1xx	xxxxx1xx	
PK1	No.2040	1527	1527	1828	825	
PK2	No.2041	-5069	-5069	-8109	-5173	
PK3	No.2042	-2691	-2691	-2028	-1307	
PK1V	No.2043	25	25	22	17	
PK2V	No.2044	-1852	-1852	-2215	-294	
PK4V	No.2046	-24708	-24708	-24708	-8235	
PPMAX	No.2053	21	21	21	21	
PDDP	No.2054	0	0	0	1894	
PHYST	No.2055	82	82	82	319	
TRQLIM	No.2060	6918	6918	6918	7282	
POVC1	No.2062	32614	32614	32614	32609	
POVC2	No.2063	1925	1925	1925	1993	
POVCLM	No.2065	5716	5716	5716	5920	
RTCURR	No.2086	1760	1760	1760	1253	
MGSTCM	No.2110	0	0	0	519	
FBND	**No.2512**	500	300	700	500	
GODMX	**No.2526**	5	6	7	5	
GODMN	**No.2527**	3	5	0	3	
GCOEF	**No.2528**	64	64	64	64	
EXGX K2	**No.2529**	-32	-32	-32	-32	
EXGX K3	**No.2530**	0	0	0	0	
EXGX K4	**No.2531**	0	0	0	0	
EXGX K5	**No.2532**	0	0	0	0	
EXGX K6	**No.2533**	0	0	0	0	

(Note 1) You need to set the Learning parameter value because of not auto-Loading.

(Note 2) These are parameters for Piston Lathe or Lead cutting machine.
You need the auto-loading by the Motor No.74 for αL9.

(Note3) After you did the auto-loading by the Motor No.285 for α*i*s8, set the following parameters.
No.2017#7=1, No.2227#2=1
No.2040= standard*1.5, No.2041=standard*1.5, No.2043= standard/2
Velocity gain 700%

Standard Parameter for Learning Control for Linear motor (2/4)

	Motor type	Lis6000B2	Lis600A1	Lis900A1		
	Motor spec.	0412	422	423		
	Motor ID	(92)	(125)	(126)		
	Velocity	0.5ms	0.5ms	0.5ms		
	Remarks	Piston Ring				
	Amplifiler	80Ap	40Ap	40Ap		
Pg	No.1825	5000	5000	5000		
PI	No.2003	00001000	00001000	00001000		
Interrupt	No.2004	00100001	00100001	00100001		
High speed	No.2005	00000010	00000010	00000010		
HS Veloc.	No.2017	00000000	00000000	00000000		
Learning	**No.2019**	x1xxxxxx	x1xxxxxx	x1xxxxxx		
Linear	No.2010	00000100	00000100	00000100		
Compatible	No.2227	xxxxx1xx	xxxxx1xx	xxxxx1xx		
PK1	No.2040	6833	720	480		
PK2	No.2041	-12667	-5537	-3691		
PK3	No.2042	-1603	-763	-763		
PK1V	No.2043	23	11	16		
PK2V	No.2044	-623	-731	-1073		
PK4V	No.2046	-14412	-24708	-24708		
PPMAX	No.2053	21	21	21		
PDDP	No.2054	1894	1894	1894		
PHYST	No.2055	319	319	319		
TRQLIM	No.2060	7282	6554	7282		
POVC1	No.2062	32670	32731	32685		
POVC2	No.2063	1222	463	1041		
POVCLM	No.2065	3626	1373	3089		
RTCURR	No.2086	1402	862	1293		
MGSTCM	No.2110	0	0	0		
FBND	**No.2512**	200	150	150		
GODMX	**No.2526**	5	15	15		
GODMN	**No.2527**	0	0	0		
GCOEF	**No.2528**	384	64	64		
EXGX K2	**No.2529**	-51	-32	-32		
EXGX K3	**No.2530**	-223	0	0		
EXGX K4	**No.2531**	-214	0	0		
EXGX K5	**No.2532**	-1	0	0		
EXGX K6	**No.2533**	137	0	0		

(Note 1) You need to set the Learning parameter value because of not auto-Loading.

(Note 2) Regarding High-gain parameter setting for the other motor, refer to **5.2 Setting High-gain parameters**.

Standard Parameter for Learning Control for HRV2 (3/4)

	Motor type	HRV2 IP	HRV2 PI	LearningHRV2		
	Motor spec.	–	–	–		
	Motor ID	–	–	–		
	Velocity	1ms	1ms	0.5ms		
	Remarks	–	–	–		
	Amplifiler	–	–	–		
Pg	No.1825	3000	3000	6000		
PI	No.2003	xxxx0xx0	xxxx1xx0	xxxx1xx0		
Interrupt	No.2004	xx0x0011	xx0x0011	xx1x0001		
HS Veloc.	No.2017	00000000	00000000	xxxxxxxx		
Learning	**No.2019**	x1xxxxxx	x1xxxxxx	x1xxxxxx		
HRV3	No.2013	xxxxxxx0	xxxxxxx0	xxxxxxx0		
PK1	No.2040	–	–	-		
PK2	No.2041	–	–	-		
PK3	No.2042	–	–	–		
PK1V	No.2043	–	–	–		
PK2V	No.2044	–	–	(standard)x2		
PK4V	No.2046	–	–	–		
PPMAX	No.2053	–	–	–		
PDDP	No.2054	–	–	–		
PHYST	No.2055	–	–	–		
TRQLIM	No.2060	–	–	–		
POVC1	No.2062	–	–	–		
POVC2	No.2063	–	–	–		
POVCLM	No.2065	–	–	–		
RTCURR	No.2086	–	–	–		
MGSTCM	No.2110	–	–	–		
FBND	**No.2512**	100	100	100		
GODMX	**No.2526**	15	13	15		
GODMN	**No.2527**	0	0	0		
GCOEF	**No.2528**	64	64	64		
EXGX K2	**No.2529**	-32	-32	-32		
EXGX K3	**No.2530**	0	0	0		
EXGX K4	**No.2531**	0	0	0		
EXGX K5	**No.2532**	0	0	0		
EXGX K6	**No.2533**	0	0	0		

(Note 1) You need to set the Learning parameter value because of not auto-Loading.

(Note 2) Regarding Learning HRV2 setting for the other motor, refer to **5.2 Setting High-gain parameters**.

(Note 3) The “xxxx” or blank frames show standard setting.

Standard Parameter for Learning Control for HRV3, HRV4 (4/4)

	Motor type	HRV3	LearningHRV3	HRV4	LearningHRV4	
	Motor spec.	–	–	–	–	
	Motor ID	–	–	–	–	
	Velocity	1ms	0.5ms	0.25ms	0.25ms	
	Remarks	–	–	–	–	
	Amplifiler	–	–	–	–	
Pg	No.1825	3000	6000	3000	6000	
PI	No.2003	xxxx1xx0	xxxx1xx0	xxxx1xx0	xxxx1xx0	
Interrupt	No.2004	xx0x0011	xx1x0001	xx0x0011	xxx00011	
Learning	**No.2019**	x1xxxxxx	x1xxxxxx	x1xxxxxx	x1xxxxxx	
HRV3	No.2013	xxxxxxx1	xxxxxxx1	xxxxxxx0	xxxxxxx0	
HRV4	No.2014	xxxxxxx0	xxxxxxx0	xxxxxxx1	xxxxxxx1	
HS Veloc.	No.2017	0xxxxxxx	0xxxxxxx	0xxxxxxx	0xxxxxxx	
HRV3 always	No.2283	xxxxxxx1	xxxxxxx1	xxxxxxx1	xxxxxxx1	
PK1	No.2040	-	-	(Standard)x1.5	(Standard)x1.5	
PK2	No.2041	-	-	(Standard)x1.5	(Standard)x1.5	
PK3	No.2042	–	–	–	–	
PK1V	No.2043	–	–	–	–	
PK2V	No.2044	–	(Standard)x2	(Standard)x2	(Standard)x2	
PK4V	No.2046	–	–	–	–	
PPMAX	No.2053	–	–	–	–	
PDDP	No.2054	–	–	–	–	
PHYST	No.2055	–	–	–	–	
TRQLIM	No.2060	–	–	5097	5097	
POVC1	No.2062	–	–	–	–	
POVC2	No.2063	–	–	–	–	
POVCLM	No.2065	–	–	–	–	
RTCURR	No.2086	–	–	–	–	
MGSTCM	No.2110	–	–	–	–	
HRV3CG	No.2334	150	150	200	200	
FBND	**No.2512**	150	200	150	200	
GODMX	**No.2526**	13	10	13	10	
GODMN	**No.2527**	0	0	0	0	
GCOEF	**No.2528**	64	64	64	64	
EXGX K2	**No.2529**	-32	-32	-32	-32	
EXGX K3	**No.2530**	0	0	0	0	
EXGX K4	**No.2531**	0	0	0	0	
EXGX K5	**No.2532**	0	0	0	0	
EXGX K6	**No.2533**	0	0	0	0	

(Note 1) You need to set the Learning parameter value because of not auto-Loading.

(Note 2) The “xxxx” or blank frames show standard setting.

(Note 3) Regarding Learning HRV3, HRV4 setting for the other motor, refer to **5.3 Setting Learning HRV3, HRV4**.

Appendix 4. **Functions table for Servo edition**

Functions \ Servo Software series	Standard				Special				
	9090	90A0	90B0	90D0	90A3	90A7	90B3	90B7	90D3
[Learning control ontrol]									
Stopping motor function at alarm happened	-	-	-	-	A	A	A	A	A
Learning buffer expanding function	-	-	-	-	A	A	A	A	A
Learning data transmission function	-	-	-	-	A	A	A	A	A
Learning buffer compelling clear	-	-	-	-			A	A	A
Self learning control	-	-	-	-	A	A	A	A	A
Self learning control improvement (Expansion Gx etc.)	-	-	-	-	A	A	A	A	A
High speed interpolation (0.25ms)	-	-	-	-			A	A	A
High speed interpolation (0.5ms)	-	-	-	-	A	A	A	A	A
High speed interpolation for 2 axes	-	-	-	-	B	A	A	A	A
Servo trace function	-	-	-	-	A	-		-	-
Auto sampling rate (Self-Learning control)	-	-	-	-	A	A	A	A	A
Shock reducing function (Self-Learning control)	-	-	-	-	A	A	A	A	A
Step Shock reducing function	-	-	-	-	A	A	A	A	A
High speed cycle cutting Skip function	-	-	-	-	A	A	A	A	A
New Hunting control function	-	-	-	-	-	-	-	-	-
Special Hunting control function	-	-	-	-	-	-	-	-	-
Velocity Control period 0.25msec	-	-	-	-	-	-	A	A	A
Velocity Integral saturation (High-speed axis)	-	-	-	-	A	A	A	A	-
Variable Velocity feedback the latest 0.25msec or 0.5msec or	-	-	-	-	A	A	A	A	
Velocity feedback the latest 2msec	-	-	-	-	A	A	A	A	
Torsion compensation during high speed cycle	-	-	-	-	A	A	A	A	B
Torsion compensation for 2 axes	-	-	-	-	B	A	A	A	-
Tandem Learning function	-	-	-	-	B	A	A	A	B
Error output through check board	-	-	-	-	A	A	A	A	-
Mcmd output through check board	-	-	-	-	A	A	A	A	-
Ultra-high precision feedback function (RON type)	-	-	-	-	-	-	-	-	-
Ultra-high precision feedback function (RCN type)	-	-	-	-	-	B	-	A	-
IP or PI variable current control	-	-	-	-	B	A	A	A	-
Notch filter by current loop	-	-	-	-	-	-	-	-	-
Max. feed forward speed 196m/min for high speed I/F axis	-	-	-	-	A	A	A	A	
Available for C series servo amplifier (Dead-band)	-	-	-	-	A	A	A	A	A
Preview repetitive control function	-	-	-	-	A	A	A	A	A
Preview repetitive control improvement (5 -> 11)	-	-	-	-	A	A	A	A	-
Preview repetitive control improvement (Posit or Veloc)	-	-	-	-	A	A	A	A	
Relieving restriction for Adaptive advanced preview control	-	-	-	-	A	A	A	A	A
Adaptive advanced preview control for 2 axes	-	-	-	-	B	A	A	A	-
Correspondence to High speed cycle retract	-	-	-	-	A	A	A	A	A
Learning data transmission function (High Speed I/F)	-	-	-	-	-	-	B	B	A
Parts Learning control function	-	-	-	-	-	-	-	-	A

Appendix 5. **Method of changing parameter in CNC Program**

1. Overview

Learning control is available only during High-speed cycle cutting (G05). You can change some parameters for Learning control in program by using G10 code (Programmable data input) before G05 execution. For example, by changing Command period (PRIOD) or Repetition count (RPTCT) by G10, you can change the rotation speed of C-axis, or control suspension of Learning control during G05.

2. Setting Method

The procedure for creating a program is as follows. You insert G10 code before the High-speed cycle cutting (G05) in program to use this function. If G10 is not used, the values which already set as servo parameter are used.

The following program example is a case of Lead cutting.

```
O0001;
.....
G10   L50;
N2516 P(axis num.) R 0 ;
N2517 P(axis num.) R 40 ;
G11 ;
G05 P10001 L1 ;
.....
(another program code)
.....
G10   L50 ;
N2516 P(axis num.) R(Learning count) ;
N2517 P(axis num.) R(Learning period) ;
G11 ;
G05 P10002 L1 ;
.....
(another program code)
.....
M30 ;
```

For example, end turning is performed at 1500 min^{-1} with G05 without using Learning control, then high-precision cutting is performed at 120 min^{-1} using Learning control.

In a left sample, Learning control is invalid during next G05 because Repetition count RPTCT (No.2516) is 0.
In this case, this line doesn't need. 1500min^{-1} = 40msec/rev

Learning control is invalid during G05 due to RPTCT=0.

You should set RPTCT in order to use Learning control during next G05. If Learning control doesn't stop halfway during G05, you should set 32767 as maximum number of RPTCT.

Set 500 corresponded with 120 min^{-1} when there are High-speed cutting data of 120min^{-1} in P-code data.

3. Cautions

(1) You should not insert the command to move servo axis between G11 and G05 such as G00 or G01.

(2) You should set, for example 3rd. axis, P**3**.

(3) You can also change the following parameters for Learning control by G10 in NC program.

No.2511	PRFNO	Profile number
No.2514	LESTTM	Learning start number
No.2518, No.2520, No.2522, No.2524		Learning count (Repetition count)
No.2519, No.2521, No.2523, No.2525		Learning period (Command period)

Appendix 6. **Parameter number difference between series 16*i* and 30*i***

	16i [90Bx]	30i [90Dx]	Remarks
Learning control	No.2008#5	No.2019#6	
Adaptive Preview control	No.2008#7	No.2019#5	
Function bits 3	No.2007	No.2442	
	No.2008	No.2443	exept #5, #7
Function bits 1	No.2228	←	
	No.2229	←	
Function bits 2	No.2226	←	
	No.2227	←	
Current PI ratio	No.2230	No.2323	fitting to standard
Maximum speed check	No.2231	No.2541	
Step repetition count	No.2232	No.2515	
Profile number	No.2233	No.2511	
Learning start time	No.2234	No.2514	
2nd repetition count	No.2235	No.2518	
2nd Leraning period	No.2236	No.2519	
3rd repetition count	No.2237	No.2520	
3rd Leraning period	No.2238	No.2521	
4th repetition count	No.2239	No.2522	
4th Leraning period	No.2240	No.2523	
Manual thinning count	No.2241	No.2535	
1st repetition count	No.2242	No.2516	
1st Leraning period	No.2243	No.2517	
Low pass filter	No.2244	No.2512	
Suspenstion cycle	No.2245	No.2513	
Maximum order of Gx	No.2246	No.2526	
Minimum order of Gx	No.2247	No.2527	
Maximum coefficient of Gx	No.2248	No.2528	
Minimum coefficient of Gx	No.2249	No.2529	
Coefficient 3 of expanded G	No.2250	No.2530	
Coefficient 4 of expanded G	No.2251	No.2531	
Coefficient 5 of expanded G	No.2252	No.2532	
Coefficient 6 of expanded G	No.2253	No.2533	
Forward order	No.2254		
Adpative coefficient	No.2255	No.2543	
Feedforward coefficient w1	No.2256	No.2544	
Feedforward coefficient w2	No.2257	No.2545	
Feedforward coefficient w3	No.2258	No.2546	
Feedforward coefficient w4	No.2259	No.2546	
Feedforward coefficient w5	No.2260	No.2547	
Feedforward coefficient w6	No.2261	No.2548	
Shock reducing counter	No.2262	No.2534	
Torsion compensation	No.2263	No.2536	
Total profile number	No.2264	No.2510	
5th repetition count	No.2265	No.2524	
5th Leraning period	No.2266	No.2525	

1. Difference of velocity loop characteristic between 90D3 series and 90B3 series

There are the difference between 90D3 and 90B3 in the characteristic of velocity loop as follows.

In 90D3 series, PK1V (No.2043) and PK4V (No.2046) are calculated automatically according to velocity sampling period.

Furthermore there are the following difference in Velocity loop high-speed proportional processing function (No.2017#7=1).

- 300Hz torque command filter becomes valid regardless of No.2067=0.
- Torque command filter (No.2067) is calculated automatically according to velocity sampling period.
- Acceleration feedback function (No.2066 < 0) is unavailable.

If you change over servo parameters from series 16*i* to series 30*i*, set compatible bit (No.2227#2) to 1.

In the detail parameter, refer to "**5.1.4 Caution in case of servo parameter setting**" and "**Appendix 6. Parameter number difference between series 16*i* and 30*i***".

2. The setting for motor ID No.74 (αL9) or No.75 (αL6)

If you use the parameter set for motor ID No.74 or No.75 on series 16*i* and transfer it to series 30*i*, refer to "Standard parameters for Learning control (1/4) in "**Appendix 3. Parameter table for Learning control**". Please modify the following parameters at an emergency stop.

Take care because the parameter No.2007, No.2008, N0.2230-No.2266 were changed at series 30*i*.

No.2005#4=1 -> 0 (High speed axis)

No.2007#0=1 -> 0

No.2017#7=0 -> 1 (Velocity loop high-speed proportional processing function)

No.2227#2=0 -> 1 (Compatible bit)

No.2066 and No.2067 leave the same value.

3. The setting for Learning HRV2 control (HRV2 control + Velocity 0.5msec.)

If you use Learning HRV2 control on series 16*i* and transfer it to series 30*i*, refer to "Standard parameters for Learning control (3/4) in "**Appendix 3. Parameter table for Learning control**".

Take care because the parameter No.2007, No.2008, N0.2230-No.2266 were changed at series 30*i*.

No.2227#2=0 -> 1 (Compatible bit)

No.2066 and No.2067 leave the same value.

If Velocity loop high-speed proportional processing function is used, No.2017#7=0 -> 1.

4. The setting for Feed-forward control with Learning HRV2 control

If you use the coefficient (No.2068) for Feed-forward control with Learning HRV2 control on series 16*i*, you should use the coefficient (No.2092) for advanced Feed-forward control on series 30*i*.

Index

- Adaptive preview control 33, 55
- Backup module for power failure 51
- Command data period (Learning period) 3, 28
- Compensation data 11,27
- Continuation mode 11,27
- Data Server operation 3,5
- DNC operation 3,5
- Dynamic characteristic compensation element (Gx) 30
- Expanded Gx (Dynamic characteristic compensation) 27,30
- FSSB 14,19
- G10 (Programmable data input) 42,61
- High gain 17
- High-speed axis 4,16,25
- High-speed cycle cutting 63
- High-speed distribution 13
- High-speed binary operation 3, 5
- High-speed proportional processing function 16,24,53
- HRV control 19
- HRV3 14,18
- HRV4 18,24
- illegal parameter alarm for Learning control 52
- Interpolated period for G05 38
- ITP delay 51
- Learning axis 4,13
- Learning memory-expanded function 36,54
- Learning data transmission function 39,54
- Low pass filter (Fc) 17,30
- Option 54
- Profile 29,36
- Profile number 36,38,40,52
- Retract 51,54
- Sampling rate 38
- Skip function 51,54
- Suspension mode 11,27
- Total profile number 36,38,40,52